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VERTEBRAL ANGIOGRAPHY: PERCUTANEOUS LATERAL ATLANTO-OCCIPITAL METHOD*

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CEREBRAL angiography is now an established and important method of investigation. Recognition of its possibilities and its employment have increased in proportion the ease and safety of its technical performance. These factors are reasonably satisfactory for the carotid vascular tree. Notwithstanding the fact that we obviously require exactly similar information concerning vertebral arteries and their circulatory field, the development of vertebral angiography lagged behind that of the carotid because of technical difficulties in performance. For really convenient usage a percutaneous method which is free from complications and yields a high proportion of successful angiograms is essential. We believe that a method which we developed—and which in our hands proved successful in a very high proportion of cases—possesses these desirable qualities, in some measure, with almost the facility of carotid angiography. Our method depends on puncturing the vertebral artery as it winds around the lateral mass of the atlas, the line of approach of the puncturing needle being a lateral one, in the plane of the tip of the mastoid process.

APPLIED ANATOMY

The vertebral artery emerges from the foramen at the base of the transverse process of the atlas. The anteromedial border of the foramen is formed by the lateral mass of the atlas, which continues cranialwards beyond the foramen, and this 'wall' of lateral mass is further continued across the lateral atlanto-occipital joint to the base of the skull by the occipital condylar mass. On leaving the foramen the artery curves rather sharply dorsally and runs on the upper (cephalic) surface of the posterior arch of the atlas in the horizontal plane, curving gently medially and lying close to the lateral mass of the atlas. At the dorsomedial extremity of the lateral mass of the atlas the artery curves inward and upward to penetrate the dura (*Fig.* 1). Within the dura it joins its fellow of the opposite side to form the basilar artery. The lateral mass of atlas and occipital condyle together constitute our deep landmark; and they provide a solid safety barrier about 2·5 cm. wide across the route of the approaching needle. The angle between this vertical wall of lateral mass of the atlas and the horizontal 'floor' of the upper surface of its posterior arch is important to successful puncturing of the artery from a lateral approach, as the artery is literally 'cornered' here by the advancing needle.

The tip of the transverse process of the atlas, often a palpable landmark in thin individuals, lies in a plane slightly posterior to the transverse foramen and it also lies virtually in the plane of the tips of both mastoid processes (*Fig.* 2). The upper surface of the transverse process forms a more or less prominent ridge anteriorly where it forms the anterior boundary of the transverse foramen and slopes upwards as it fuses with the lateral mass of the atlas. It slopes outward and downward towards the tip, the anterior portion of which is flat (due to absence of an anterior tubercle); the posterior (dorsal) part as a rule possesses a short upward projection which can be easily avoided by the needle advancing at the level of the upper surface of the process.

The mastoid process varies greatly in size and shape, the tip (lowermost part), however, lies as a

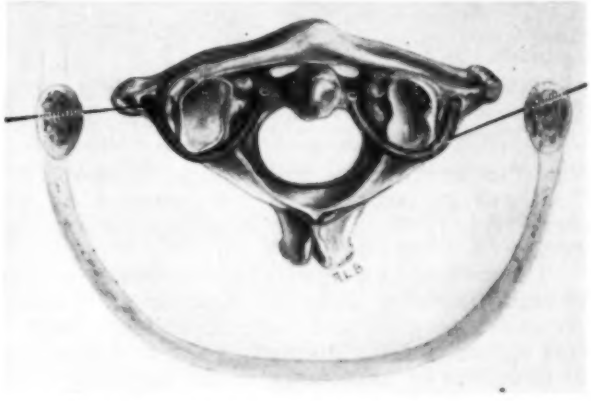


FIG. 1.—Drawing of atlas and axis from above, showing the course of the vertebral artery around the lateral mass of the atlas. The left side shows the line of approach under the tip of the mastoid in the plane vertical to the midline. On the right side the point of needle entry is in front of the tip of the mastoid and the artery can be punctured in a more oblique manner. Note the safety of either approach.

* Based on a preliminary report read at the meeting of the British Society of Neurological Surgeons, Birmingham, December 2, 1950.

rule in the vertical and also the horizontal plane of the foramen transversarium, and forms our landmark for insertion of the needle. If the mastoid process is short (*Fig.* 3, left side), the plane of the needle is strictly horizontal; if, however, the mastoid process is large or the anterior ridge of the transverse process prominent, the point of insertion is above and *in front* of the tip of the mastoid process and the needle is directed very slightly downward (caudad) and dorsally (*Figs.* 1, 3, right sides).

FIG. 2.—Lateral view showing relationship of mastoid process, transverse process of atlas, and vertebral artery.

Note that even in this more oblique approach the theca and its contents are still protected by the lateral mass of the atlas and superimposed condylar mass.

The muscles in the path of our approach (sternomastoid, posterior belly of digastricus, splenius, longissimus capitis, and superior oblique) form a firm support for the inserted needle and there are no structures of importance in the pathway. The first cervical nerve emerges between the vertebral artery and the upper surface of the arch of the atlas and is of no significance in respect of needle puncture.

TECHNIQUE

A study of routine axial and lateral radiographs of the skull is adequate to discover any individual anatomical variations; and in particular the depth of the lateral mass of the atlas and the size of mastoid process. No special views are required. It should be noted that the relationship of the skull to the atlas vertebra varies with flexion and extension of the head. A position of flexion is the most convenient for the purposes of this puncture.

We prefer and advise general anæsthesia and endotracheal intubation.

The patient is placed face up with neck flexed. The Schonander skull radiography apparatus is convenient and should be adapted to take serial films in horizontal and vertical axes without rotating the head of the patient. Once the needle is in situ extension of the head on the neck for the submentovertical projection, should this view be desired, is easily achieved without disturbing the needle.

Novocain infiltration is used sparingly—skin weal as a marker at the tip of the mastoid process, no solution for the track in the muscles, and then 1–3 c.c. of 2 per cent solution up against the lateral mass of the atlas. Excess of novocain overdistends the tissues and the artery becomes less 'fixed' and it tends to become elusive in the novocain-sodden

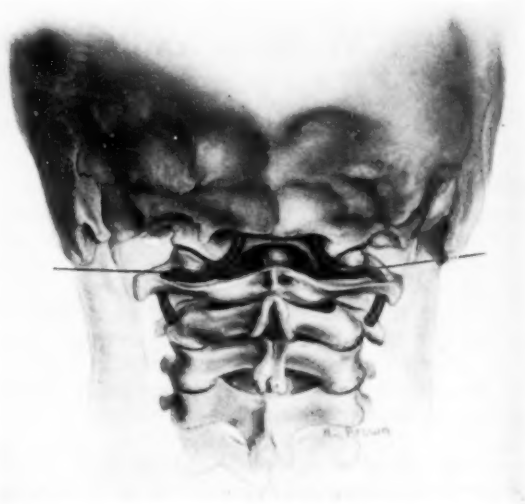


FIG. 3.—Atlanto-occipital region and vertebral arteries viewed from behind. The plane of introduction of the needle on the left side is horizontal as the mastoid process is short. On the right side the mastoid process is shown to be more prominent and so is the anterior ridge on the transverse process of the atlas; the point of entry of the needle is *in front* and above the tip of the mastoid.

tissues. Lately we have made the first puncture without any local anæsthetic and find that this facilitates the speed of entry; if, however, the first few attempts are not successful yet the artery has been punctured, we do inject small quantities of anæsthetic locally to obviate development of vasospasm. It is convenient to use routinely for infiltration a standard length of needle—5–7 cm.—and to use the occasion for a reconnaissance of the deeper landmarks—namely, the upper surface of the transverse process of the atlas and the lateral mass of the atlas.

The puncture needle is 8 cm. long, 17 gauge, 45° bevel point, and a special 'head' adapted to fit transparent plastic tubing; 25 cm. of this tubing is permanently attached to the needle and at its proximal end to a Record syringe adaptor. A 20-c.c. syringe, tubing, and needle are loaded with sodium citrate solution. The needle is entered through the skin as close to the tip of the mastoid process as possible. It is advanced medially, strictly in the axis of the crossing of horizontal and vertical planes—that is to say, at right angles to the sagittal plane. At a depth of 1–2 cm. one may contact the tip of the transverse process of the atlas, and the needle should be adjusted to pass closely above it. If no such contact is made the needle can be safely advanced farther, provided we keep the needle at right angles to the sagittal plane, until the lateral

mass of the atlas is encountered—in an average adult at a depth of about 5 cm. from the skin. The needle can then be manipulated into the groove (or 'corner') between the wall of the lateral mass and the upper surface ('floor') of the posterior arch of the atlas. This is done by short withdrawals, posterior tiltings, and re-insertions of the needle, making contact with bone on each occasion. On one of these occasions the artery will be punctured—an event signalized at once by the rush of blood under arterial pressure into the transparent connecting tube. The needle is then manipulated so as to advance the point into the lumen of the artery.

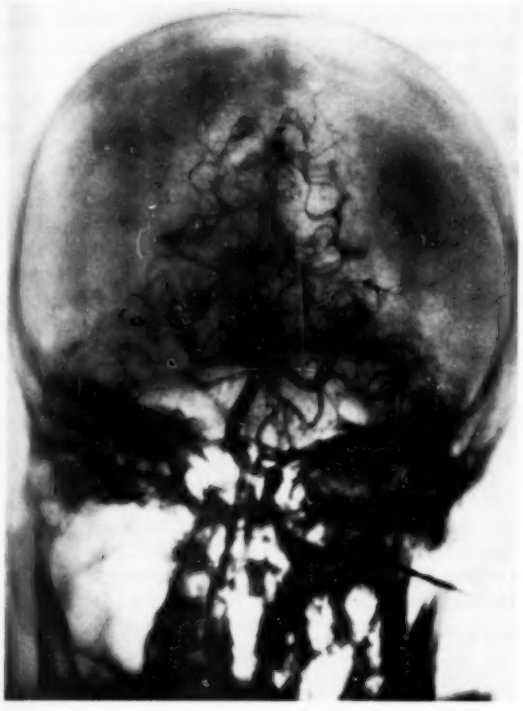


FIG. 4.—Vertebral angiograms, arterial phase in 30° fronto-occipital projection (Towne's view).

FIG. 5.—Vertebral angiogram, arterial phase in Towne's projection. Note excellent retrograde filling of the opposite vertebral artery.

The bevel of the needle must point dorsally or cephalad so that the injection it emits is directed distally in the arterial lumen. If the bevel is directed proximally in the artery a retrograde filling of the vessel may result.

A trial saline injection is made to test how securely the needle is engaged in the lumen of the

FIG. 6.—Vertebral angiogram, arterial and early venous phase in lateral projection.

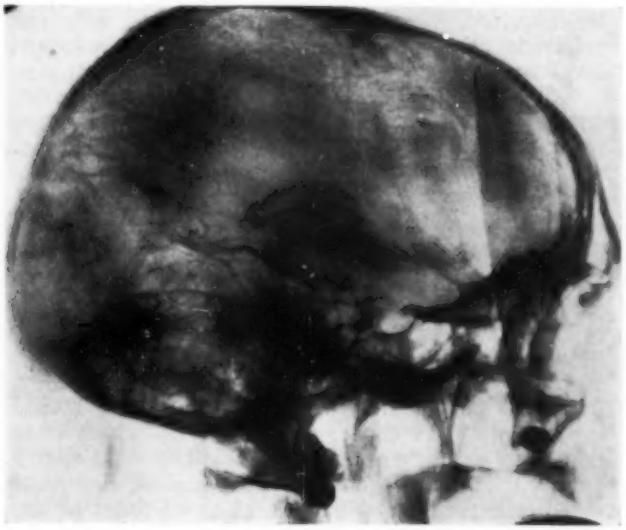


FIG. 7.—Vertebral angiogram, venous phase in lateral projection.

artery and then injections of contrast medium are made and stereoscopic radiography is conducted in the usual way. We use 14–16 c.c. of 35 per cent iodopyracet preparation for each injection. Commonly four injections are used for lateral and axial views. We consider stereoscopy essential to exploit to the full the value of vertebral angiography.

Stereo-lateral and 30° fronto-occipital projection are used routinely. In addition straight fronto-occipital projections are employed for supratentorial

FIG. 8.—Vertebral angiogram, arterial phase in submentovertical projection. Note filling of contralateral vertebral artery.

lesions. At times submentovertical projections may be required. We have given as many as eight injections in one session without any untoward sequelæ.

The technical details vary according to the patient and the projection. Exposures have ranged from 0·2 to 0·8 sec., using 65–80 kV. with 200 ma.

RESULTS

The lateral atlanto-occipital method has been employed by the author in 104 cases—53 in the Royal Infirmary, Edinburgh, where the method was evolved (the first time in June, 1950) and a further 51 cases in Salford Royal Hospital and Crumpsall Hospital, Manchester, and Royal Manchester Children's Hospital, in association with Dr. E. Batley. Including our earliest attempts, we failed to secure angiograms in 11 cases; in several the results were not up to a standard comparable with carotid angiography, though adequate for exclusion of any gross vascular anomalies. Reproductions of some of the normal vertebral angiograms are illustrated in *Figs.* 4–8.

The method described above has been used as a routine in cases where there were indications for vertebral angiography. The youngest patient was 12 years of age.

The time spent on successful puncture of the vertebral artery was variable, depending on various factors, such as the calibre of the artery (perchance starting on the side with a small vertebral artery) or even on the operator's degree of determination to secure satisfactory angiograms. Children were found more difficult; men were better subjects for vertebral angiography than women.

Almost without exception the vertebral artery was punctured by our approach within the first minute or two after insertion of the needle through the skin, but not always 'squarely' enough to proceed with injections. Re-entry on the same side, or (if clotting in the needle began to interfere with free arterial flow from the needle), on the opposite side, may take a little time before the needle is sufficiently securely in the lumen of the artery to allow freely any number of injections and any type of projection. In 40 per cent of our first 50 cases the time spent to attain such secure entry of the needle into the lumen of the vertebral artery occupied less than 5 minutes; in another 40 per cent under 20 minutes. In a few it took us half an hour and in one an hour. The average time occupied was 13·4 minutes. In the last 40 cases the time of secure entry was never longer than 30 minutes; in 70 per cent it was under 5 minutes, in the remainder 10–15 minutes; 1 or 2 cases took nearly half an hour (in 3 cases the angiogram was postponed (and successful afterwards) on account of excessive tendency to clotting in needle and tubing and it was considered unsafe to proceed with the further punctures at that time). The number of injections of the contrast medium varied from three to eight; in the last 32 cases of the Edinburgh series the average number of injections amounted to 5·37 per case; in the last 40 cases we did not exceed five injections. A 35 per cent solution of iodopyracet is used for lateral projections, occasionally 42 per cent for fronto-occipital projections. The amount of solution per injection varies from 10 to 15 c.c. according to requirements.

FAILURES AND DIFFICULTIES

Our failures and some of the poorer results were attributable to: (1) Facing the bevel of the needle proximally, which may interfere with distal filling in this small artery. (2) Using too much local anæsthetic in a thin-necked and small individual (boy, aged 14) which disposes to too easy dislodgement of the needle and also makes the artery more elusive in the novocain-sodden tissues. (3) Using a needle of too large a bore or with too long a bevel—we are adjusting the gauge of the needle to the 'build' of the individual. (4) Misinterpretation of anatomical conditions (in 1 case mistaking an unusually deep groove at the atlanto-condylar joint for the 'corner' between the upper surface of transverse process of atlas and the lateral mass of atlas). (5) Unusual anatomical conditions such as unusually large mastoid process with 'high' atlas and bulbous tip of the transverse process; though in these rare circumstances, in one case unintentionally, in the

second deliberately, we punctured the artery below the transverse process, that is between the foramina transversaria of the axis and atlas, and secured satisfactory angiograms. (6) Restricting ourselves in earlier cases to attempting angiography on one side only, which reduces the chances of success as not infrequently the vertebral arteries vary considerably in calibre between one side and the other. (7) Attempting puncture through a tumour substance which has compressed the vertebral artery, the tumour having spread down and outward from above the foramen magnum. (8) In one case, congenital absence of the arch of the atlas associated with platybasia.

Clearly some of these causes of failures are avoidable if due attention is given to details. With experience a higher percentage of success should be attainable.

COMPLICATIONS

The complications that we encountered are, I believe, inherent in vertebral angiography and not dependent on the particular method used.

We had 1 death which should be considered attributable to vertebral angiography :—

A woman of 31 of good health suddenly lost consciousness, which was followed on recovery by severe occipital headaches, dizziness, vomiting. After two days she developed abruptly without loss of consciousness left-sided hemiplegia which had shown little recovery at the time of admission several hours later; remainder of examination showing nothing definitely abnormal. Right carotid angiography (3 injections of 35 per cent arteriodone, 13–14 c.c. per injection, under general anæsthesia —nitrous oxide plus oxygen via endotracheal tube) did not disclose any abnormality. Left vertebral angiography carried on—the vertebral artery entered quickly but needle dislodged half-way through injection; artery re-entered within few minutes and angiography completed without any untoward signs, using three injections of 12–14 c.c. each of 35 per cent arteriodone. We then tested, as on frequent occasions before, how well and firmly the needle is held in the lumen of the vertebral artery; this was done by rotating slowly the head 45° to the right from the sagittal plane, then similarly to the left side, i.e., side of puncture, while allowing the blood to flow freely from the needle throughout these manœuvres; the needle was then withdrawn. About two minutes later the patient suddenly ceased to breathe—she was quickly re-intubated and artificial respiration maintained; spontaneous breathing recurred after eight minutes, but despite our resuscitative measures she died ten hours later.

On post-mortem examination a solid thrombus was disclosed in the left vertebral artery extending from just proximal to the origin of the postero-inferior cerebellar artery to proximal 2 cm. of the basilar artery; there was also a small amount of blood in the subarachnoid spaces at the base of the brain. We assume that there was a temporary stagnation of blood in the segment of the vertebral artery between the site of puncture and the point of junction with the opposite vertebral artery. This stasis was caused by temporary diversion of blood-flow through the puncture needle during our manœuvring of the head, the large calibre of the needle virtually obstructing the lumen of the artery—these factors and the trauma of puncture of the arterial wall (two punctures) favoured the formation of thrombo-embolism, which, having involved the postero-inferior cerebellar and basilar arteries, led to a fatal issue.

In another case a woman of 41 was suspected of harbouring a vascular lesion in the posterior fossa. Vertebral angiography (three injections of 12–13 c.c. of 35 and 42 per cent pyelosil) was followed by left-sided hemiplegia, which recovered virtually completely within a few months. There were a few minor complications, the result of temporary impairment of effective tissue nutrition in the territory of supply of the vertebral arteries. In one case we noted temporary nystagmus, vomiting, and retarded recovery of consciousness from anæsthetic (after six injections); in another after three injections there were transient pupillary changes and unilateral muscular hypotonia which recovered within two hours, and undue somnolence which recovered within a day or so.

The only unusual complication was development of an arteriovenous fistula in a young man who was undergoing investigations for a spontaneous subarachnoid hæmorrhage. Following bilateral carotid angiographies which showed no lesion, vertebral angiography was carried out without any difficulties (artery entered within two minutes) and this also proved negative. The cause of his intracranial hæmorrhage remained obscure. The patient was seen again a year later complaining of an intracranial bruit which he said had ensued about two weeks after vertebral angiography. The bruit was most clearly audible with the stethoscope over the right mastoid process and it was typical of an arteriovenous fistula. We repeated vertebral angiography, using the anterior route (Lindgren; Sugar) which failed to disclose the fistula satisfactorily, but the patient on recovery from anæsthetic reported disappearance of the bruit and this was also confirmed by auscultation. Since then the patient has remained perfectly well and symptom-free for over a year. Whether this unique complication should be considered a special risk of our technique, or as a risk present in any percutaneous approach, is rather debatable. The artery is closely associated with surrounding veins at all available sites for puncture. As far as I am aware no such complication has yet been reported by others.

DISCUSSION

OUTLINE OF OTHER METHODS OF VERTEBRAL ANGIOGRAPHY

There are several methods of vertebral angiography and these can be divided into operative and percutaneous methods.

The first deliberate vertebral angiography was performed by the pioneer of intracranial angiography, Moniz (Moniz, Pinto, and Alves, 1933), by means of operative exposure of the subclavian artery and injection of contrast medium in a retrograde manner with simultaneous occlusion of the subclavian artery distal to the point of injection. This approach was used later by Krayenbuhl (1941) and others. Olivecrona (1935) injected the exposed vertebral artery directly. Sjöqvist (1938) also employed a direct technique, obtaining good filling in 6 out of 8 cases. N. M. Dott and G. L. Alexander used operative exposure of the origin of the vertebral artery, introducing the curved needle into the subclavian artery and negotiating the tip of the needle into the opening of the vertebral artery. Berczeller and Kugler (1937) described a technique of injection of the vertebral artery at the level of the atlas during

posterior fossa explorations; and Ecker (quoted by Sugar, Holden, and Powell, 1949) succeeded in doing this during suboccipital craniotomy. Radner (1947, 1951) described and performed vertebral angiography by means of a rubber catheter introduced into the exposed radial artery, and its tip negotiated (under fluoroscopic screen) into the subclavian artery opposite the orifice of the vertebral artery, and then the injections of contrast medium were made.

A percutaneous method was introduced by Shimidzu (1937), who substituted Moniz's operative approach by a percutaneous one—puncturing the subclavian artery by a needle inserted (local anæsthetic) at the middle of the lower border of the supraclavicular triangle immediately above the clavicle; the axillary artery was compressed by an assistant during the injection.

Takahashi (1940) described a percutaneous technique of vertebral angiography depending on puncture of the first part of the vertebral artery, i.e., between its origin from the subclavian and its entry into the foramen transversarium of the sixth cervical vertebra.

Sugar, Holden, and Powell (1949) described a percutaneous technique of puncturing the vertebral artery in its course through the foramina transversaria of the lower cervical vertebræ. The needle is introduced through the skin from the front, medial to the outward-retracted sternomastoid muscle and carotid sheath, until the transverse process of the fifth cervical vertebra is encountered; the needle is negotiated over the anterior superior margin of the transverse process about 1 cm. medially from the tip of the process, it enters the foramen transversarium immediately above, where it usually encounters the vertebral artery; sometimes the artery is punctured as it passes between the transverse process. In "more than 20 successive deliberate vertebral angiograms done . . . failure to fill the vertebral artery has occurred only twice". Lindgren, independently from Sugar and others, evolved a percutaneous method by a similar approach, and introduced it in 1949 at a meeting of neuroradiologists in Rotterdam and reported in 1950 success in rather more than two-thirds of 60 cases. Ecker (1951) relies on retrograde filling of the vertebral artery from a routine carotid angiography puncture, the carotid artery being occluded by digital compression distal to the point of needle entry and the axillary artery also being occluded by an assistant. Retrograde filling of carotid and subclavian arteries is achieved and thence into the vertebral artery.

EVALUATION OF METHODS

It is difficult to compare advantages and disadvantages of any method with others when one's experience is almost entirely confined to a particular technique. However, a limited experience in other methods and theoretical consideration of the relevant literature permit one to draw more or less unbiased conclusions.

Disadvantages of our technique, we believe, are those inherent in vertebral angiography and are equally shared by other methods.

Death and other serious complications attributable to vertebral angiography by other methods have been reported by several writers with larger series of cases. Radner (1951) has encountered 4 serious complications, 2 of them fatal, in 200 cases. Olsson (1952), however, in 240 cases (including 100 cases of Radner after the final elaboration of catheterization technique) reports no fatalities. Sjogren (1952), who favours anterior percutaneous puncture, and had no deaths in 200 cases, quotes Hauge's (1951) experience of 2 fatalities in 160 cases of vertebral angiography by Radner's method. Richter (1952), who employs either Lindgren's or our method, does not mention any complications in 30 cases.

Penetration of the dura by the needle is possible with a faulty technique, such as disregard for landmarks. Excessive lateral rotation of the head with the needle in situ, especially if the point of entry into the artery is dorsal to the lateral mass of atlas, may lead to penetration of the dura. Even in these circumstances puncture of the spinal cord is not possible.

The atlanto-occipital region possesses a rich venous plexus and a hæmatoma may occur. This may have a nuisance value in that it tends to block the needle and so masks its entry into the artery. The use of citrate and possibly of siliconized needles should obviate this difficulty.

Danger to the operator's hands from the close vicinity of the site of the puncture to the field of X-ray exposure is easily overcome by using a sufficient length of plastic tubing connexion; and the protective screen can be lowered over the neck as the needle remains firmly in position.

A disadvantage of this method is that it is not suitable for children under 12–14. In these cases we have slightly modified Ecker's technique. We employ a curved needle (about a quarter-circle) which is introduced into the right carotid artery with its tip directed proximally. This allows a strong retrograde injection and leaves sufficient space above for the digital occlusion of the carotid artery.

Probably the greatest obstacle in accepting and employing the method is a psychological factor. One's mental picture of the region, particularly in the lateral view, is very hazy soon after passing one's higher surgical examination! We would strongly recommend that anyone interested in the technique should refresh his memory by anatomical dissections. This exercise confers an appreciation of spatial relationships, adds to one's confidence, and results in 'safe passage'.

The advantages of the methods seem to us to outweigh the disadvantages and difficulties. Our results, which include our early attempts, compare favourably with those of other percutaneous methods. Even open operative techniques can be disappointing. Of the other methods, only Radner, by catheterization via the radial artery, managed to achieve 100 per cent success in his last 100 cases of 221 angiographies performed. His technique, however, has not so far been so eminently successful in the hands of others, and Sjogren believes that percutaneous and catheter methods are successful in approximately the same frequency but that the anterior percutaneous method has certain practical advantages, such as less complex equipment permitting carrying out vertebral angiography in conjunction with carotid angiography, and no risk associated with fluoroscopy. The experience and

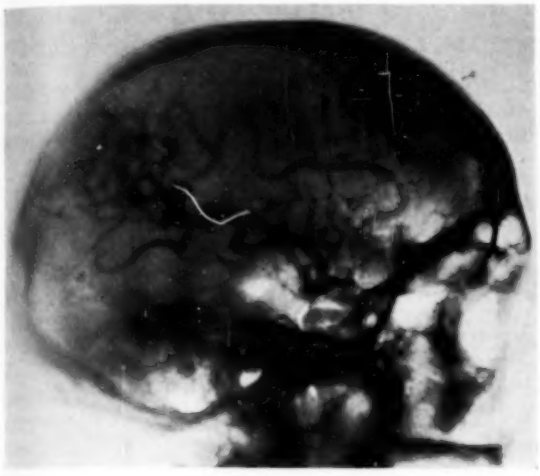
high percentage of successes with our percutaneous approach would support Sjogren's views of the advantages of percutaneous over catheterization techniques.

Of percutaneous methods the lateral atlanto-occipital approach offers the best chances of securely engaging the vertebral artery. The reasons are clearly shown in *Figs.* 1, 2. The vertebral artery at the level of the atlas presents a wider target and its gently curved course allows greater 'play' and greater 'threading' of the needle into the artery, thus reducing the chances of dislodgement during injection (*Figs.* 5, 6). The injection, being given nearer the basilar artery with a less easily dislodged needle, is capable of producing sharper contrasts in the radiographs. There are dependable bony landmarks and a measurable depth for engaging the artery, and with reasonable care the needle point cannot go far astray and it does not need any external support, being firmly held in position by muscles below the mastoid process.

Access to both vertebral arteries is of importance (apart from increasing chances of success), as it is preferable to inject the vertebral artery on the side of the lesion in order to secure filling of its posterior inferior cerebellar branch. Apart from the anterior approach of Lindgren, Sugar, and others, other methods as a rule are confined to the right side only. Furthermore, in the atlanto-occipital puncture the point of injection being nearer the junction with the opposite vertebral artery, it is often possible to achieve retrograde filling of that vessel also (*Fig.* 5).

The atlanto-occipital approach is more comfortable to the patients, and they do not complain as a rule of any pains after the procedure, whereas in vertebral angiography by anterior percutaneous route, not infrequently some degree of injury with needling sustained by brachial nerve-roots, hæmatoma, irritation by extravasated dye, can cause unpleasant and sometimes persistent complaints referable to upper limb.

Finally, the atlanto-occipital approach is eminently suitable in cases of saccular or cirsoid aneurysmal formations on the borders of vertebral and carotid circulatory fields where discovery of accessory feeding vessels from the other system is essential. This we can establish by the 'anteroposterior cross-circulation test', that is, injection of vertebral artery with simultaneous digital occlusion of the appropriate carotid artery. In atlanto-occipital vertebral angiography the cross-circulation between vertebral and carotid fields can be easily established—there being unimpeded access to either carotid artery for digital occlusion. We first demonstrated this in a case quoted by Gillingham (1953). *Fig.* 9 also illustrates this point; carotid angiography revealed a large cirsoid aneurysm seemingly supplied only by carotid circulation. Vertebral angiograms showed some fine additional connexions from the posterior cerebral artery. Vertebral angiography with occlusion of the carotid revealed these additional



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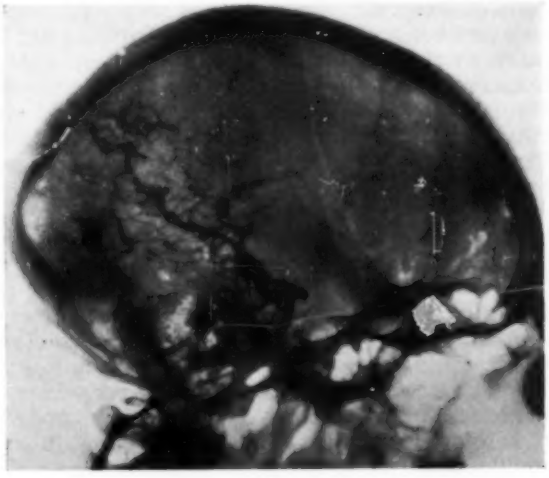

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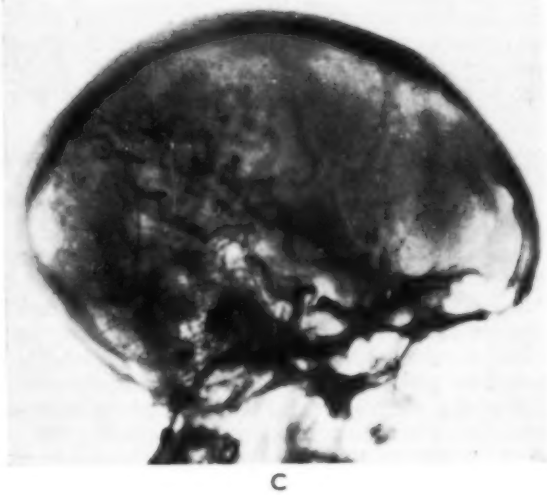

C

FIG. 9.—A, Carotid angiogram showing vascular malformation in right parieto-occipital region. Feeding arteries arise from middle and anterior cerebral arteries.
B, Right vertebral angiogram showing clearly the additional blood-supply to the malformation arising from the posterior cerebral artery.
C, The right vertebral angiogram with simultaneous digital occlusion of the right carotid artery. The malformation is filled now not only by posterior cerebral artery but also by middle cerebral artery via posterior communicating artery. Futility of carotid ligation as a method of treatment of such a malformation is visualized.

vessels more clearly; it also demonstrated the futility of carotid ligation in these cases, as well as the inadequacy of occlusion of some of the larger feeding vessels only, as it has been from time to time recommended.

The value of any auxiliary method of examination increases with its ease and safety of performance. We trust that though our method has not proved infallible, a very high proportion of successful angiograms justifies a wider trial. Even if it may not be equally successful in other hands I believe that it will become an important part of the armamentarium of neuroradiologist and neurosurgeon. Having two or three reasonably successful methods of examination at our disposal, we should rarely fail to secure satisfactory vertebral angiograms.

SUMMARY

A new method of percutaneous vertebral angiography is presented. It depends on puncture of the vertebral artery at the atlanto-occipital level from a lateral approach. It has been employed in 104 cases, with 11 failures. Applied anatomy and technique is described. Causes of failures and complications are discussed. A brief outline of other methods in use is given and comparative evaluation of our method is attempted.

I wish to express my deep gratitude to Professor N. M. Dott for permitting me to develop the method in his department and for his guidance and invaluable help in preparation of this paper. I also wish to thank Miss A. L. Brown, from the Department of Medical Illustration, Edinburgh University, for her excellent drawings. My sincere thanks are also due to the staff of the Radiological Departments of Royal Infirmary, Edinburgh, Salford Royal Hospital, Crumpsall Hospital, and Royal Manchester Children's Hospital, for their untiring co-operation in developing this method of angiography.

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RADICAL PNEUMONECTOMY FOR BRONCHIAL CARCINOMA

BY SIR RUSSELL BROCK AND L. L. WHYTEHEAD

SINCE 1947 one of us has been performing a radical operation for bronchial carcinoma consisting of a block dissection of the mediastinal lymph-nodes, in addition to total removal of the lung at the site of origin of the main bronchus and vessels. This was briefly described in 1948 (Brock, 1948, a), when it was called 'block dissection pneumonectomy'; and again, somewhat more fully, in a chapter in *Recent Advances in Surgery* (Brock, 1948, b), but we have so far given no full account of the operation and its results. This report, although somewhat tardy, has the advantage that we have been able to verify our opinions and conclusions by adequate trial and experience. In addition to ourselves, the radical operation is used by many other surgeons who have observed it, either as assistants or as visitors. The term 'radical pneumonectomy' is preferable as it is in keeping with radical operations for cancer of other organs.

Rationale of Radical Pneumonectomy.—Pneumonectomy or, in certain selected cases, lobectomy is now performed regularly in all thoracic surgical clinics for bronchial carcinoma. In spite of the inherent gravity and malignancy of this disease the operation cures many patients and can give several years of relief to many others. Statistics are steadily accumulating showing 5-year, 10-year, and even 15-year cures, with many patients free from recurrence for shorter periods. One of us has 1 patient alive sixteen years and 3 patients over ten years after operation, in addition to many over five years.

The operability rate, however, still remains disturbingly low and the early recurrence rate disturbingly high, so that it is desirable to improve our operative technique as much as possible to increase the first and lower the second. Radical pneumonectomy, as described here, can do both of these things. There is still no satisfactory or hopeful treatment for bronchial carcinoma other than operation.

The lung is an organ richly supplied with blood-vessels and lymphatic connexions, and it is not surprising that early dissemination occurs, especially as in many cases the growth is biologically of a highly invasive nature. It is often too late to achieve cure or even long-term freedom from recurrence, especially if distant vascular metastases have already occurred. That is, unfortunately, an only too common mode of spread. In many others, however, the chief spread is local and by way of the lymphatic system, and any operation that aims at complete cure must seek to achieve a wide local extirpation of the disease, including as radical a removal of the

associated lymphatic field as possible. Only in this way can we hope to improve the percentage of cures or of long freedom from recurrence.

This observation is a truism so far as all cancer surgery is concerned and it has governed the design and evolution of all good cancer operations in any part of the body. The best example, radical mastectomy for carcinoma of the breast, is an operation that, correctly and carefully performed, gives some of the best results in surgery for a condition which little more than fifty years ago was associated with such bad results after the incomplete operations then in vogue that responsible surgeons even advised against any attempt at operation.

Although, in general, the nature of bronchial carcinoma is far more malignant than mammary carcinoma, there is every reason why the same principles of radical removal should be applied to it and that the lesser procedures should be discarded, except in selected cases.

Historical Evolution of Operation for Bronchial Carcinoma.—The great development of modern lung surgery really dates from the epoch-making work of Brun (1929) and of Shenstone and Janes (1932) on one-stage lobectomy for bronchiectasis. A number of surgeons had performed lobectomy successfully before this; Tudor Edwards in this country had even performed a successful dissection lobectomy in 1929 and had removed several lung tumours (Edwards, 1939). The work of Shenstone and Janes, however, provided a safer and simpler method, the efficacy of which was shown by the rapidly increasing number of successful operations performed by many surgeons. The success in removing bronchiectatic lobes soon encouraged use of the same tourniquet technique for the removal of carcinoma. Roberts and Nelson (1933) in their report of 10 cases of one-stage lobectomy recorded an example. The tourniquet method was obviously unlikely to be applicable to more than an occasional case and then with only scant hope of cure.

In April, 1933, Graham (Graham and Singer, 1933) performed the first successful pneumonectomy for a bronchial carcinoma, using a modified tourniquet technique; the patient, an obstetrician, is still alive and well nearly twenty-two years later. In July, 1933, Rienhoff performed the first true dissection pneumonectomy; the patient was a child with a sarcoma of the lung. Soon after this, Rienhoff used the same operation for removal of another lung tumour which proved to be an adenoma.

Dissection pneumonectomy, that is, removal of the lung after dissection in the hilum of the individual vessels and the bronchus and their separate ligation and suture, soon became the standard method of treatment of bronchial carcinoma and has, of course, supplanted the tourniquet method for all conditions requiring pneumonectomy.

After 1933 there was steady general improvement in the details of the operation, particularly in methods of bronchial closure. Then came the valuable suggestion by Allison (1946) of the use of intrapericardial ligation of the vessels in certain cases in which adhesion to or invasion of the pericardium made pneumonectomy otherwise impossible. Allison very properly pointed out that fears of entry into the peritoneum and the pleura had been shown to be false and that there was no reason why the pericardium should be any less tolerant of interference. This has been shown to be true from the very large number of intrapericardial operations that are now safely performed as a routine.

There is no doubt that intrapericardial exposure of the vessels combined with resection of any part of the pericardium to which the growth may be adherent enables the lung to be removed when it would otherwise be impossible to do so. It is the natural next step in our policy of applying the operation of pneumonectomy as often as possible. Considered in this way, however, it is only a technical elaboration. If we are to design and practise a radical cancer operation based on principles accepted for other organs in the body we must go further and use it routinely and combine it with a block-dissection of the mediastinal tissues and lymph-nodes.

Since this radical procedure was first planned and performed by one of us in 1947 (Brock, 1948, a, b) several other surgeons have used and described variations of pneumonectomy combined with block removal of mediastinal nodes. Thus Cahan, Watson, and Pool (1951) and Weinberg (1951) give clear accounts of operations in which the various lymph-node groups are removed, but failure to remove a collar of the pericardium or to take the vessels at their origin and so leave the inner wall of the hilar box intact, means that their operation is not truly radical. Kirklin and Jampolis (1953) discuss intrapericardial dissection in left pneumonectomy combined with a clearance of the mediastinal lymph-nodes (not very precisely described). They, however, do not advocate routine pericardial resection, but apply this step in only certain cases; they do not discuss their policy with carcinoma of the right lung.

More recently, Higginson (1953), in an article entitled "Block Dissection in Pneumonectomy for Carcinoma", described an operation which he has been using since 1948 which is very similar to the one we describe here. Incidentally he is the only author who ascribes priority of devising and describing this operation to us.

Surgeons in most countries no doubt are using various modifications of pneumonectomy, with or without routine pericardial resection and with varying degrees of lymph-node clearance.

THE BASIS OF RADICAL PNEUMONECTOMY

The basis of any good cancer operation consists of: (1) Total extirpation of the affected viscus together with the investing fascia and the adjacent fascial and other tissue connexions into which growth commonly extends or is likely to extend; (2) Block removal of the associated lymphatic field.

1. Total Extirpation of the Lung together with Adjacent Vulnerable Tissue.—It is common at operation for a bronchial carcinoma to find that extension of growth has occurred medially along the pulmonary veins or the pulmonary artery into the hilum of the lung so that dissection of the hilar structures is difficult or impossible. For instance, the growth may have extended along the superior or inferior pulmonary vein as far as the pericardium

and may even surround the vein as a firm collar. In these circumstances the operation must either be abandoned or the pericardium must be opened and an attempt made to secure the veins within it. This is the basis of the intrapericardial resection proposed by Allison. The matter is, however, much more important and significant than this. Recognition of this common mode of spread into the loose areolar tissue around the hilar vessels and towards the pericardium indicates that there must be cases in which a cellular spread has begun although gross anatomical invasion of growth is not yet evident. In other words, it can never be safe to leave this hilar tissue behind, even in an apparently early case, and, moreover, it must be bad cancer surgery even to disturb it by dissecting through it to expose the vessels for ligation. Hilar dissection pneumonectomy for bronchial carcinoma, the operation in common use to-day, is therefore untenable on theoretical grounds. *Intrapericardial exposure and ligation of the vessels should be practised in every case.* In addition, in order to avoid disturbing the hilar connective tissue rich in lymphatics, it is necessary in every case to excise an oval of pericardium completely surrounding the hilum. This area of pericardium is also the area first affected by cells spreading medially through the direct hilar route. Its removal is, therefore, essential on two grounds: conservation of the hilar tissue space and excision of a potentially affected membrane.

What applies to the veins applies equally to the artery; spread of growth in its fascial investment or involvement of lymph-nodes around it may reach so far medially that the operation is very difficult or quite impossible with a hilar dissection technique. If gross infiltration can occur in this way less coarse, clinically undetectable, cellular infiltration may already be present in an apparently early case, and dissection and ligation of the vessel at the usual site in the hilum will result in dissemination or in infected tissue being left behind. The artery must, therefore, never be touched in the hilum but must be secured at its very origin, at which site it is partly intrapericardial and partly extrapericardial.

Similarly, the bronchus must be secured at its highest level and interfered with as little as possible lower down. It is the general custom to-day to cut the bronchus high and obliquely at its junction with the trachea. This is done to ensure good healing and to minimize fistula formation, but it is equally desirable on the grounds of radical cancer surgery.

If the lung is not adherent to the parietal pleura in any part the above considerations satisfy the first premise. If, however, pleural adhesions are present, these must also be dealt with as radically as possible. It is true that they may be old and due to a long-spent infection; or they may be due to sepsis secondary to the growth and not to the growth itself. The safest course is to treat them as suspect or contaminated and perform an extrafascial separation from the chest wall and not just divide them. This is particularly important if the adhesions are to the mediastinal pleura, which, in such cases, should be completely removed over the adherent area together with the lung. Incidentally this extrafascial separation of pleural adherence, in addition to being sound cancer surgery, is a much easier technical method of freeing the lung. When the mediastinal pleura is widely excised it also exposes the operative field fully for the next step that we have to consider, namely, block dissection of the mediastinal lymphatic field.

2. Block Removal of the associated Lymphatic Field.—The rich lymphatic connexions of the lungs and the early widespread glandular involvement that is so often seen has led to sceptical pessimism in the minds of many as to the possibility of satisfactory radical lymphatic extirpation. We have been informed by pathologists that observation at autopsy on cases dying of bronchial carcinoma shows lymphatic dissemination within the chest in regions quite inaccessible to any operation, however radical. This attitude has hindered advancement in many branches of therapeutics. The observations in the dead-house made on subjects dying of a disease are not necessarily relevant to the state of affairs present at an earlier phase in the illness. We do learn from the observations of this late picture and in some part we base our treatment on it, but we must not allow it to deter us from rational or even hopeful efforts.

Anatomy of the Mediastinal Lymph-nodes.—The accompanying diagrams from Rouvière (1932) (*Figs.* 10, 11) show the general arrangement of the chief groups of lymph-nodes. Those present on both sides are the ones in the ligamenta lata, often closely applied to the œsophagus, also various nodes on the surface of the œsophagus at any level up to the superior thoracic inlet, and the group in the anterior mediastinum; the inferior tracheobronchial group is also largely common to both sides. In addition, on the *right* side are two groups of great importance; these are the glands in the right tracheobronchial fossa, and the lower anterior tracheal group. The first of these is fed from the rich lymphatic pathway leaving the upper part of the right hilum and lies in a deep fossa which enables it to be quite extensively enlarged without any obvious surface projection. This fossa is roughly a tall pyramid in shape, with its base resting on the upper border of the lung hilum and crossed by the vena azygos. Its posterior wall is the trachea and its anterior wall the superior vena cava, which converge above; in its medial wall is the aortic arch covered by the fibrous expansion of the outer layer of pericardium; its roof or lateral wall is formed by mediastinal pleura.

The second, or anterior tracheal, group is not so well recognized; indeed, it is not mentioned by Rouvière, but is of great practical importance. Numerous large lymphatic vessels, often mistaken for nerves or small blood-vessels, stream towards it from the lung across the space in front of and above the right pulmonary artery (Brock, 1940); these dangerous pathways are inevitably disturbed and ruptured in hilar dissection. The nodes of the anterior tracheal group lie in close association with the lowest part of the anterior surface of the trachea extending to the right to lie in front of the anterior surface of the origin of the right main bronchus with an isthmus-like connexion above with the right lateral tracheobronchial group and below with the inferior tracheobronchial group. To the left the anterior tracheal group may appear to be delimited, although it, of course, receives important lymphatic

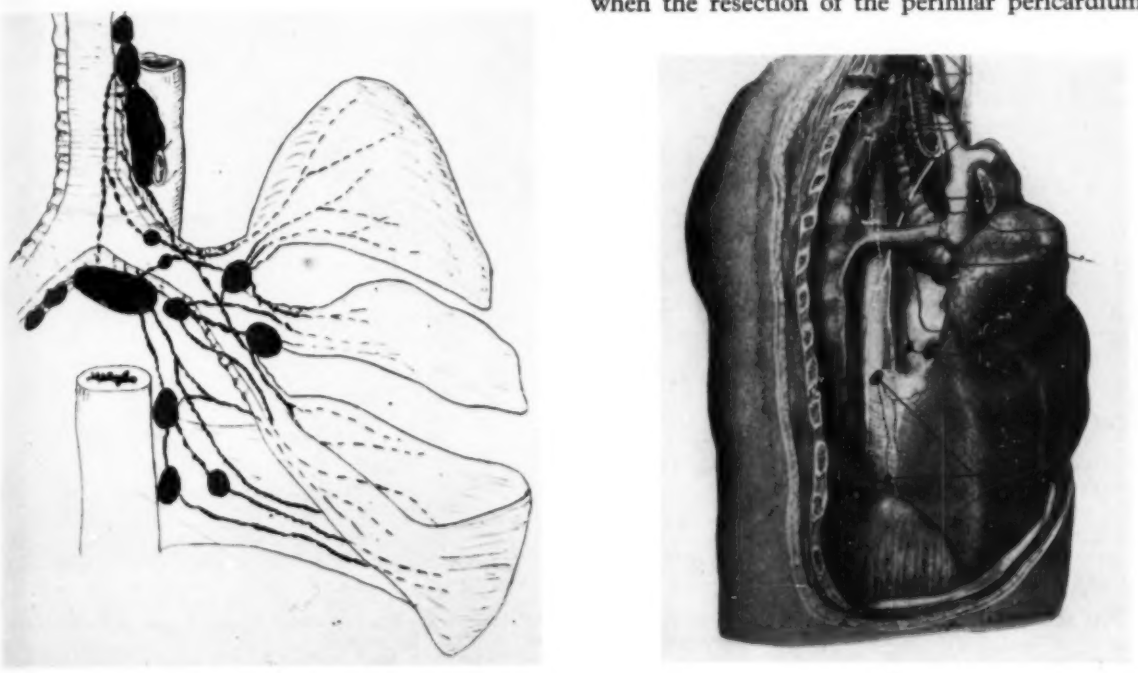
vessels from this aspect. It has a greater or lesser degree of continuity with the left tracheobronchial group of nodes which lies in the concavity of the aortic arch and projects to both the medial and lateral sides of the arch. This group is in close relation to the left recurrent laryngeal nerve, and if the anterior tracheal group of glands is properly removed in the operation of right radical pneumonectomy, the *left* recurrent laryngeal nerve should be displayed as it lies on the medial aspect of the aortic arch.

On the *left* side the intervention of the aortic arch makes the left tracheobronchial group less precise than the corresponding right group. Lymph-nodes are found closely applied to the left main bronchus on its posterior aspect above and also in front in close relation to the left pulmonary artery along which they may extend a good way medially. These nodes are in series with the group which lies in the concavity of the aortic arch in close relation to the ligamentum arteriosum and the left recurrent laryngeal nerve, which is accompanied by nodes as it passes below and to the medial side of the aortic arch (*Fig.* 12). As already stated, this group, the left tracheobronchial, may be directly joined to the anterior tracheal group or it may be separated by a short gap which must, however, carry large and important lymph channels. In the same way as on the right side a chain of nodes, smaller than the right tracheobronchial group, extends upwards to the superior thoracic inlet anterior to the trachea.

These nodes, as well as those of the right tracheobronchial group, are also connected with three or four isolated nodes which lie, on each side, in the anterior part of the superior mediastinum, lateral to and below the thymus gland.

The *inferior* tracheobronchial group (*Fig.* 10 A) lies in the inferior tracheobronchial fossa formed above by the carina and diverging main bronchi. The fossa is closed below virtually by approximation of the posterior aspect of the pericardium over the left atrium, with the œsophagus and aorta behind. It is reinforced by fairly firm fascial walls and is well displayed in the operation of radical pneumonectomy when the resection of the perihilar pericardium has been completed. Some of the nodes in this group are chiefly concerned with one or other lung, i.e., those lower ones closely applied to the medial aspect of the related bronchus. There is considerable admixture in the upper nodes of the fossa, particularly the conspicuously large one that is usually present. In any event the close relation and interconnexion of these nodes compel their total ablation whenever possible. Clean removal is often tedious and difficult owing to dense adherence to the carina or to either bronchus from old scarring; the numerous small branches from the related bronchial arteries that supply the nodes are also a potential source of trouble unless they are secured meticulously.

The inferior tracheobronchial nodes are, of course, freely interconnected with all the other groups mentioned.



A B

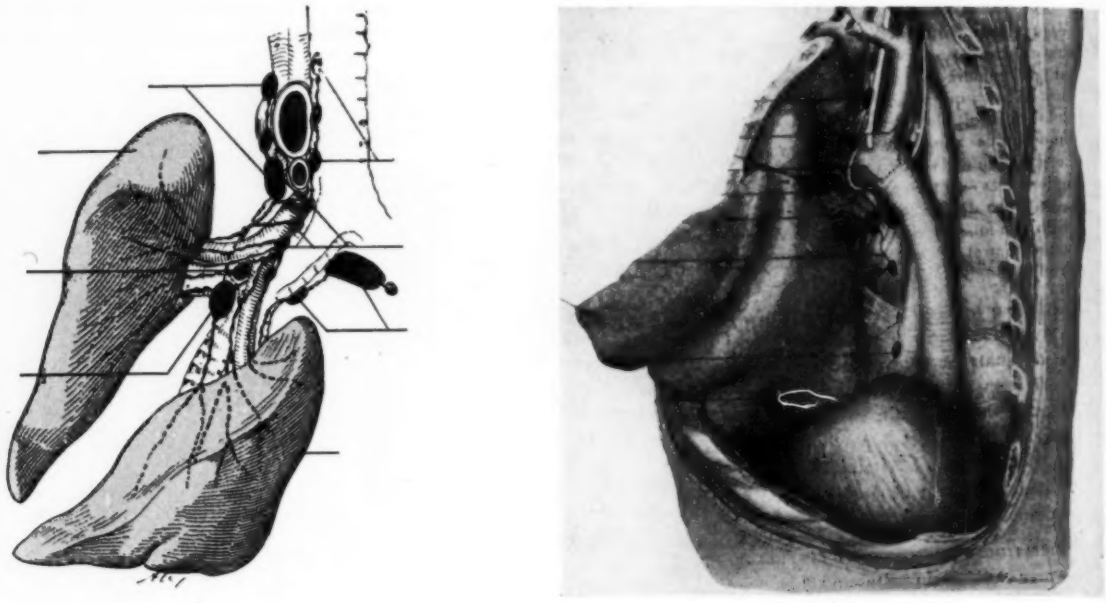
FIG. 10.—A, B, Diagrams to show the lymphatic drainage of the right lung. (*Reproduced by kind permission from Rouvière's "Anatomie des Lymphatiques de l'Homme" (Paris: Masson et Cie).*)

PREVENTION OF VASCULAR SPREAD

Aylwin (1951), writing from Allison's clinic, has contributed an important article on the avoidance of vascular spread during the actual operation for resection of bronchial carcinoma.

He postulates that as erosion of pulmonary veins in bronchial carcinoma is common, contamination

of the general circulation at operation should be avoided by tying the veins in the pericardium before manipulating the tumour. Without this modification in technique he thinks it is wrong to assume that all subsequent vascular deposits are unavoidable. He describes two cases of massive malignant emboli during pneumonectomy and puts forward convincing arguments that smaller ones may be frequent.



A B

FIG. 11.—A, B. Diagrams to show the lymphatic drainage of the left lung. (*Reproduced by kind permission from Rouvière's "Anatomie des Lymphatiques de l'Homme" (Paris: Masson et Cie).*)

There can be no doubt that this suggestion of securing the veins within the pericardium as a first step is logical and praiseworthy and should be followed whenever possible. In practice, however, we have found it is often not possible or not expedient to do this. For instance, a large adherent growth, or a large adherent mass of obstructed pneumonic lung, may make it almost impossible to reach the pericardium and the veins as a first step. Also, if a large mass of growth extends along the pulmonary artery, or high up the bronchus, or into the hilar nodes, it may not be possible to judge operability until these structures have been dissected. If the veins had been first tied it would be unfortunate if the lung was later found to be irremovable. In our subsequent description of the radical operation it should be taken that in favourable cases the pericardium should be opened and the veins secured as a first step, but we do not recommend this as a routine procedure.

THE OPERATION OF RADICAL PNEUMONECTOMY

We have performed the operation only through a long posterolateral incision either through the rib bed or with resection of the whole length of the 5th or 6th rib and sometimes with division of the back end of one rib above or below. An anterior approach does not give adequate exposure of the various parts of the large operative field. For this reason also we have not used the face-down position in which much of the anterior dissection, especially the right side, would be impeded. Our basic technique to avoid spill-over infection is to use an occluding endobronchial balloon or contralateral endobronchial intubation and then, as soon as the chest is opened, to identify, clear, and clamp the bronchus as a first step. This gives absolute control of secretions while the various manipulations of the lung are carried out. The policy of securing the veins first has already been discussed.

The steps of the operation are sufficiently different on the two sides to need separate descriptions.

THE RIGHT SIDE

As securing the bronchus is to be the first step, the lung is gently held forwards with a retractor so as to expose the reflection of the pleura from the posterior aspect of the hilum and a longitudinal incision is made over the bronchus. The vagus nerve is identified, freed, and displaced backwards. It is occasionally possible to define the bronchus and to free it without further dissection, but usually it is necessary to divide at least one and sometimes two large bronchial vessels on its posterior surface. In addition branches from the vagus may need dividing; as these are almost invariably accompanied by small vessels, it is best either to ligate them or to apply silver clips (*Fig.* 13).

At this stage it is usually necessary to ligate and divide the vena azygos, although if the bronchus can be freed safely without doing it so much the better. This is because as little manipulation as possible should be done before the bronchus is safely clamped. The meticulous freeing and division of the vena azygos in the best place demands a certain amount of forward and downward displacement of the upper lobe. A compromise is to tie and divide the vein

just above the posterior part of the hilum to allow access to the bronchus and then later complete the more careful dissection of the vein in front where it joins the superior vena cava after traversing the fossa.

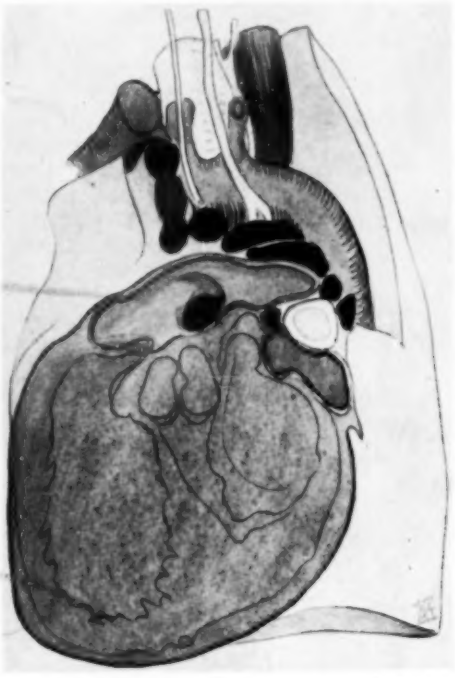


FIG. 12.—A sagittal section transecting the left main bronchus and showing the left tracheobronchial group of nodes.

The clamp used on the bronchus is a light non-crushing one which inflicts no damage. When the bronchus has been clamped the block dissection of the mediastinum is begun. *Fig.* 14 shows the order and disposition of the incision in the pleura at the various stages. If the upper lobe is widely adherent, as mentioned earlier it is freed extra-fascially and so the upper mediastinum will be exposed. Failing this the incision in the mediastinal pleura is continued upwards to the superior thoracic inlet along the line of the vagus nerve; a short transverse incision is then made forwards so as to expose the region of the phrenic nerve and the pericardiophrenic vessels. Starting from above, the right tracheobronchial compartment is opened posteriorly; the peripheral stump of the vena azygos is displaced and search made for any nodes that may lie deep to it. At the superior thoracic inlet the right subclavian and innominate veins are exposed and all fatty and lymph-node tissue is taken from them until the origins of the pericardiophrenic vessels are clearly seen; these vessels are then ligated and divided; the phrenic nerve is cut. The incision in the pleura is now carried downwards to meet the hilum once more; this can be done in one of two ways. Either straight down just in front of the phrenic nerve, or with a wide anterior sweep to include exposure of the anterior mediastinal nodes. If this is done it is better to avoid including any thymic tissue; the opposite pleura is also vulnerable in this area. If this forward extension is used the pleural incision returns to the line in front of the phrenic nerve just above the vena azygos and is continued down for 2–3 cm. The phrenic nerve with its surrounding fat and vessels is now freed backwards so as to lay bare the superior vena cava

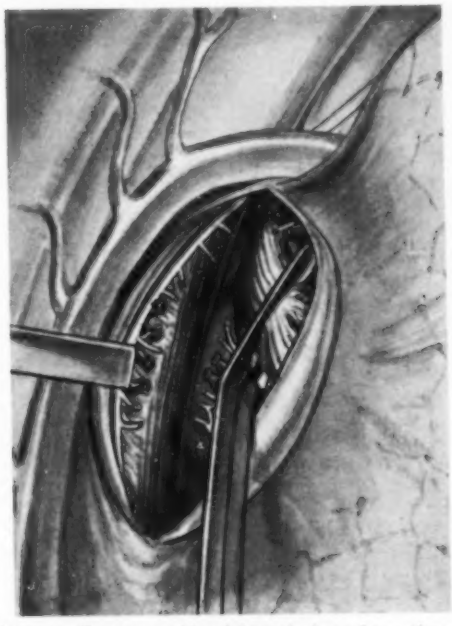


FIG. 13.—Exposure of the right main bronchus; the vagus nerve has been displaced posteriorly after its branches and the bronchial vessels have been divided.

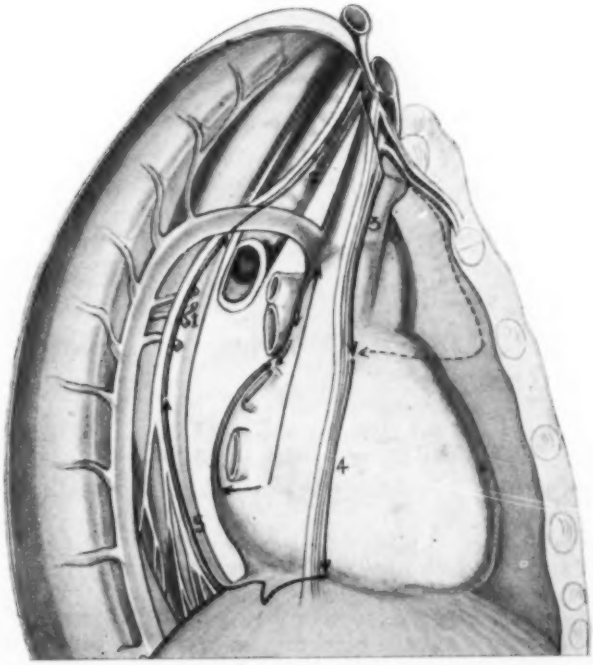


FIG. 14.—Diagram to show the disposition and order of the incisions in the mediastinal pleura and also in the pericardium. The numbers and arrows indicate the order and direction of the incisions.

and origin of the vena azygos; this vein is then ligated at its entry into the superior vena cava. If a long stump of about 1 cm. is left this will be found

very useful to displace the vena cava in later stages of the dissection. The vein should not be disturbed as it crosses the fossa, but should be divided behind and in front. The contents of the fossa are now dissected from the superior vena cava; it will be found that the fossa is some 2 cm. deep and contains a surprisingly large mass of nodal and fatty tissue. This is freed above at its 'apex' and also medially until the fascia covering the aortic arch is displayed.

FIG. 15.—After the right tracheobronchial fossa has been cleared and the phrenic nerve and vessels freed and displaced, the exposed pericardium is opened.

The whole block of tissue can now be displaced downwards, leaving the deep fossa empty.

At the lower end meticulous care is needed to free all tissue lying across the superior surface of the right main bronchus where the arch of the azygos vein lies. Antero-inferiorly the lymph-node group is connected with the anterior tracheal nodes and it is better to leave the complete dissection of this region until later.

The incision in the pleura is now carried right down to the diaphragm, in front of the phrenic nerve, which is freed and displaced backwards throughout its length so as to expose the fibrous pericardium. Five ml. of 0·25 per cent decicain (amethocaine) are now injected into the pericardial sac, and while this is allowed one to two minutes to act the phrenic nerve is ligated with its accompanying vessels, immediately above the diaphragm. The pericardium is now opened about 1·5–2 cm. in front of the hilum (*Fig.* 15) at the level of the inferior pulmonary vein and the veins secured.

The small serous mesentery passing from the inferior vena cava to include the inferior pulmonary vein (*Fig.* 16) is confusing unless its construction and presence are remembered. This is incised and it is then a simple matter to pass a finger below and behind the inferior pulmonary vein until it encounters the reflection of serous pericardium at the upper margin of the superior vein. This is incised and the finger then completely encircles the common vein at its entry into the left atrium. A single

FIG. 16.—The common pulmonary venous trunk is secured. Note below how the venous mesentery between the inferior vena cava and the inferior pulmonary vein has been deliberately cut open.

ligature is passed around the common trunk and the origin of the superior and inferior tributaries displayed so that a separate ligature can be placed around each of these.

If growth has extended along either vein as far as the pericardium this manœuvre will effectively circumvent a great or otherwise impossible difficulty. In some cases growth may have involved the pericardium, extended on to the common vein of entry, or even reached the wall of the left atrium itself. Such cases are often inoperable, but the extension does not necessarily preclude safe removal, and in this disease removal should be pressed to all reasonable limits. The line of division can be made

through the wall of the atrium itself, either by applying a suitable soft clamp such as Crafoord's aortic clamp or, better still, a curved clamp of the serrated edge type introduced by Potts, or by inserting a row of interlocking mattress sutures across the atrium and cutting distal to them.

The next step is the dissection of the artery, and for this the pericardial incision is extended as high up as possible. If a finger is inserted a small recess will be found that runs for about 2 cm. along the lateral aspect of the superior vena cava, well above the level of the pulmonary artery; the pericardium should be *opened right to the upper limit of this recess*. The free exposure given by the operation now begins to be revealed. It will next be found that the reflection of pericardium from the lateral surface of the superior vena cava is thin and serous, the fibrous layer being also very delicate in this area. What little fibrous extension there is can now be divided upwards so as to open fully into the lowest part of the right tracheobronchial fossa. By progressive dissection in this way the superior vena cava is mobilized, and it can then be easily displaced forwards so as to display almost the whole length of the right pulmonary artery from above and in front. The vena cava can be easily manipulated by using the stump of the ligated vena azygos if this was left long for the purpose. In this position the artery is covered partly by serous pericardium (in front) and is invested with a thin layer of fascia derived from the outer layer of the pericardium (Brock, 1940). It is now a simple matter to free the artery *well within the mediastinum* and behind the lower end of the mobilized superior vena cava (*Fig.* 17). Quite apart from avoiding interference with hilar lymphatics, this manœuvre allows the artery to be secured quickly and safely well medial to a growth which extends so far across the front of the hilum as to make removal impossible or dangerously difficult by the ordinary hilar exposure. The lymphatic channels in this region are of great practical importance, for many large lymphatic vessels stream across from the lung to the anterior tracheal group of nodes in the tissue spaces in front of the artery. It is clearly desirable to avoid disturbance of these large lymph vessels as far as possible.

With the superior vena cava fully mobilized in this way, the pericardium opened in front and the mediastinal pleura incised from top to bottom, it will now be seen what an enormous exposure is provided; it is almost as if the mediastinum is opened like a book. Although the exposure may be thought severe and radical, it is in fact safer than a more limited exposure and makes for much greater ease and speed in exposing and securing the vessels.

The artery is now ligated and divided; two proximal ligatures are used on this vessel the distal one of which is a transfixion ligature.

The pericardial incision is now carried around to the back of the heart to meet the upper end of the original incision in front. As the lung is held forwards and upwards the inferior tracheobronchial fossa is fully displayed and its contained lymph-nodes can be simply and cleanly removed under direct vision (*Fig.* 18).

It is after this stage that it is best to return to the dissection of the anterior tracheal nodes which were exposed in the early stages of the operation. Both the inferior tracheal and the right tracheobronchial nodes have an isthmus-like connexion with the anterior tracheal group, and the dissection of both groups should be continued so that all the nodes are exposed in continuity. The previous mobilization of the superior vena cava and the division of the right pulmonary artery allow complete and easy exposure of the whole of the lower end of the trachea (*Fig.* 19). The anterior tracheal nodes can be dissected with confidence and certainty and, as stated earlier, the criterion of a good clearance is that one should see the *left recurrent laryngeal nerve*; this is necessary in order to define the left limit of the anterior tracheal nodes or to follow them as far as is desirable if they are in direct continuity with the nodes lying in the concavity of the aortic arch. The justification of this step in the operation was seen in a case in which the *left* recurrent nerve was found involved by a malignant node from a carcinoma of the *right* lung.

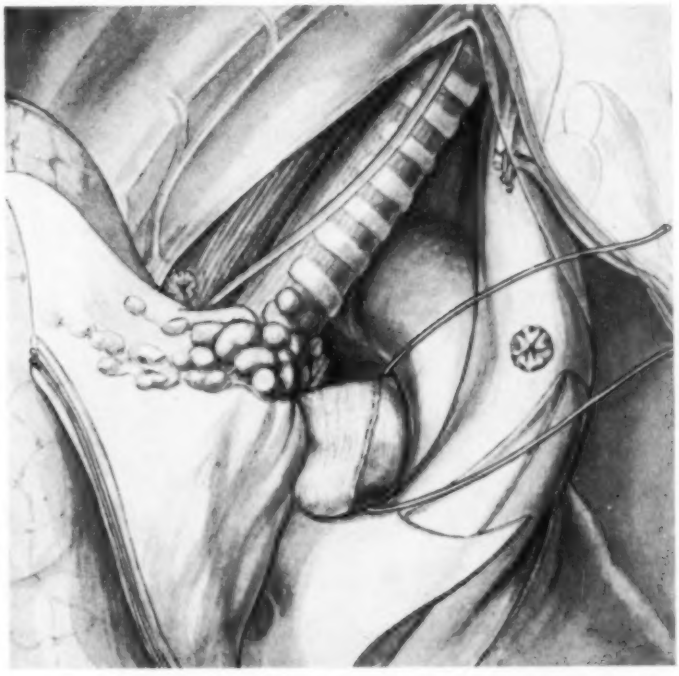


FIG. 17.—The main right pulmonary artery has been cleared and freed deep in the mediastinum; observe the medial rotation and displacement of the superior vena cava. The artery is partly covered by serous pericardium. Note the exposure of the aortic arch.

The final step is the division and closure of the bronchus. Our present technique is simple and has been found to give excellent results. Fine stainless steel wire is used, mounted on atraumatic needles. Figure-of-eight sutures are passed around the clamp; four to six sutures suffice. The clamp is then removed and the sutures are tied (*Fig.* 20 A, B). We feel that the most suitable structure to cover the bronchial stump is mediastinal fascia and not pleura.

Apart from anything else, very little pleura is available after a radical operation.

The vagus nerve is connected to the lateral surface of the œsophagus by a mesentery-like fold

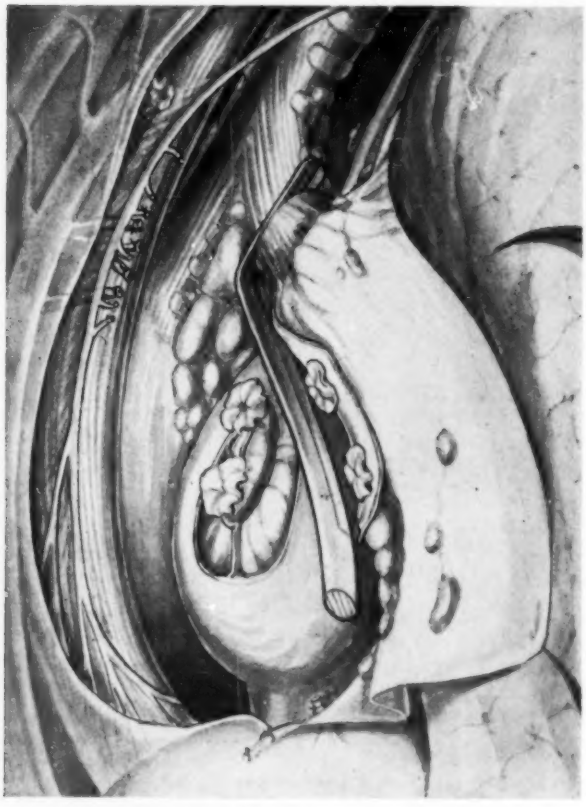


FIG. 18.—The resection of the perihilar pericardium has been completed and also all the lower lymph-node clearance. The inferior tracheobronchial compartment is now clearly exposed for deliberate dissection.

In some cases it is necessary to sacrifice the vagus nerve; it may even have to be divided just below the superior thoracic inlet if it is involved in a glandular mass. On the left side we have often had to divide the vagus nerve just above the hilum and resect it with the lung. In these cases the bronchus is left uncovered.

It is impossible, undesirable, and unnecessary to close the pericardial defect, although the question is often asked. A large piece has been resected and suture, if it could be achieved, would cause tamponade. It is much safer to leave the sac to drain into the pleura; the defect in any case is closed by sero-serous adhesion in 24–48 hours. Care must be taken to avoid prolapse of the heart, which can readily occur if the defect is too large. This can be guarded against by inserting a few sutures to diminish the size of the aperture, and in cases in

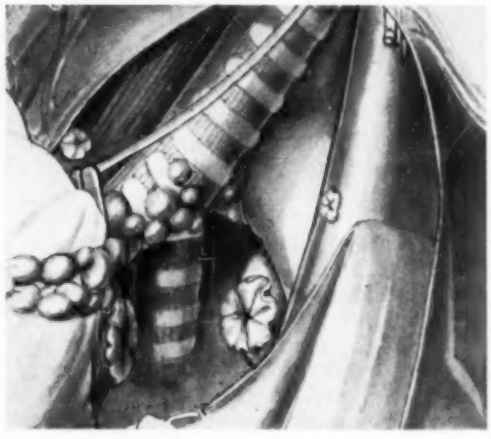
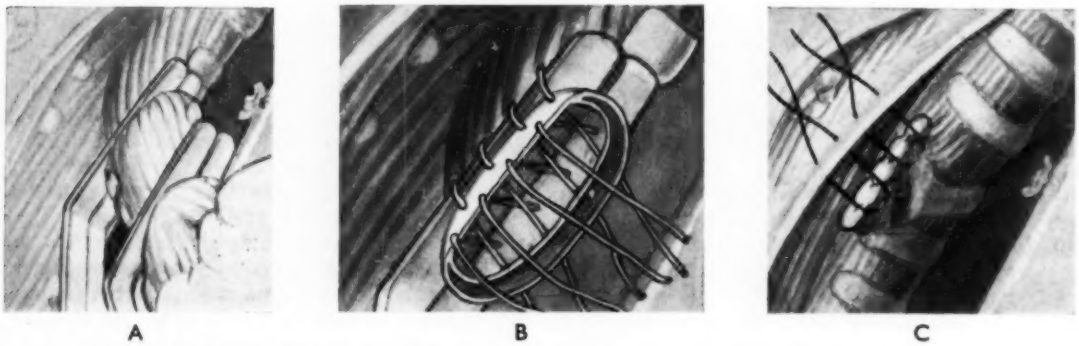


FIG. 19.—The final stage of the radical operation on the right side is completed by dissecting the anterior tracheal group of nodes in continuity with the right and the inferior tracheobronchial groups. Note how the *left* recurrent laryngeal nerve is exposed; the anterior tracheal glands are usually connected with the subaortic group.



A B C

FIG. 20.—To show the steps of bronchial closure and coverage. For full details see text.

of firm fascia and this is conveniently placed and easily used to cover the bronchus; if necessary the outer edge of the œsophagus may even be rolled over the suture line. The fascia is tacked down to the anterior surface of the bronchus by two fine linen thread mattress sutures (*Fig.* 20 C). It is sometimes possible to cover the bronchus with a mobilized flap of parapericardial fat.

which it appears likely to occur, ensuring that the patient does not turn on his right side for two to three days.

THE LEFT SIDE

Fig. 21 shows the disposition of the incision in the pleura and pericardium. As on the right side, the incision in the mediastinal pleura begins behind

the hilum in order to expose the main bronchus. The vagus is defined and a plane of entry found lateral to it so that the nerve can be displaced backwards (*Fig.* 22). Once the bronchus has been secured the incision in the pleura is continued along the line of the vagus up to the superior thoracic inlet; the left innominate vein is exposed, the pericardio-phrenic vessels are identified, ligated, and divided, and the phrenic nerve is cut. There is rarely need to interfere with the internal mammary vessels. The pleural incision is now continued downwards in a wide sweep to include the anterior mediastinal pleura and continues backwards to meet

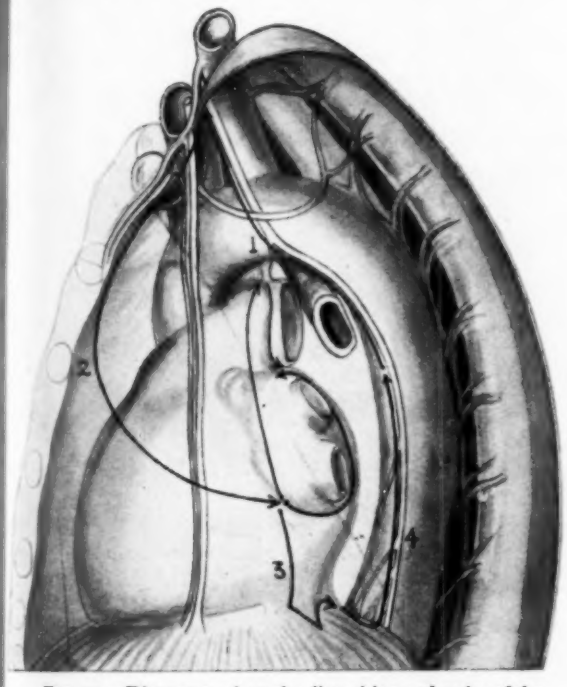


FIG. 21.— Diagram to show the disposition and order of the incisions in the pleura and in the pericardium, indicated by numbers and arrows.

the phrenic nerve and vessels about the lower limit of the hilum. At this level the nerve is freed, ligated with its vessels, and divided. It is usually not necessary to resect the nerve right down to the diaphragm, as on the right side. The whole of the mediastinal pleura, connective tissue, and lymph-nodes are now freed downwards and backwards over the aortic arch until the upper part of the fibrous pericardium is laid completely bare (*Fig.* 23). The floor or medial limit of the dissection is the fascia which extends upwards from the aortic arch and everything superficial to this is dissected away; in front the right pleura is vulnerable. The phrenic nerve is pushed back to the hilum and the pericardial sac is opened; the pericardial incision is continued below and behind the inferior pulmonary vein so as to allow a finger to pass behind the common venous trunk and to demonstrate the line of serous pericardial reflection above the superior vein. Once this has been divided the veins can be dealt with as on the right side.

It is best now to continue the block dissection by clearing the nodes disposed above the left bronchus, between it and the pulmonary artery, and occupying the angle between the vagus trunk and its recurrent laryngeal branch; this group, the lowest tracheobronchial nodes, of course, passes medially under the aortic arch. Careful dissection may be needed to free the vagus and its recurrent branch; it may be that a firm adherent mass lies in the angle formed by the two nerves and the vagus is even directly involved by growth. In such cases no hesitation need be felt about dividing the nerve below the recurrent branch. The nodes should then be carefully peeled from the recurrent laryngeal nerve itself, which must be clearly identified. If at this stage the nerve seems inextricably involved, it is best to leave the dissection for the time being.

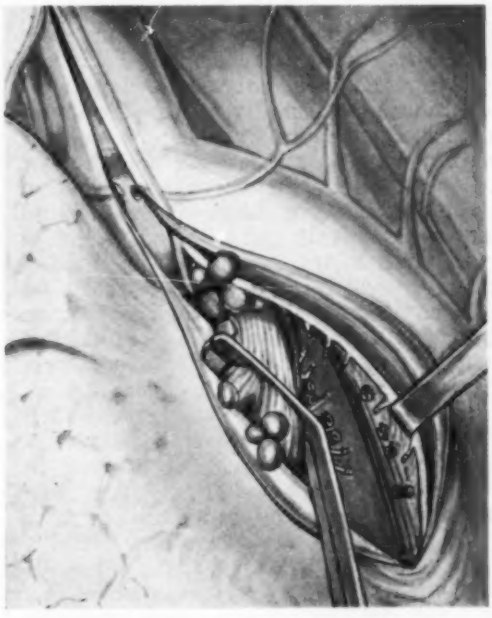


FIG. 22.—The exposure of the left main bronchus; the vagus nerve has been freed and displaced posteriorly after its branches and the bronchial vessels have been cut.

In any case, when this group of nodes is enlarged, it is safer not to follow it under the aortic arch until a wider exposure has been achieved.

The pulmonary artery should now be secured and this is done by carrying the pericardial incision (as was done on the right side) well above the level of the artery; in fact the sac is opened as far as the aortic arch. Here the pulmonary artery is partly intrapericardial, partly extrapericardial; firm or even strong expansions of the outer fibrous layer pass between it and the ligamentum arteriosum and the aortic arch. After the serous pericardial covering has been divided the artery will, as on the right side, be found to be invested with a thin covering of fascia derived from the fibrous pericardium. It is important, if the artery is to be quickly and easily freed, that this layer should be defined, incised, and the dissection carried around within it. If this is not done a great deal of time may be spent in difficult and dangerous dissection. The artery is freed in this way *at its very origin*, immediately lateral to the ligamentum arteriosum, which is itself also defined and freed so that the first ligature can be

passed medial to it (*Fig.* 23). If the artery is freed and secured in this manner it is often possible to free it safely, medial to growth that extends a considerable distance along it and which would defeat all attempts to secure the artery by the usual hilar route, which in any case disturbs infected or potentially infected tissue. After the first ligature has been passed and tied medial to the ligamentum arteriosum a second ligature is passed lateral to it; this should transfix the artery (*Fig.* 24).

In many cases the ligamentum arteriosum is deliberately divided so that the subaortic fossa is widely opened to give a perfect exposure for clearance of the nodes which it is now convenient to deal with. Even when the ligamentum is not divided the exposure obtained is usually excellent and allows a confident clean clearance. At this stage also the recurrent laryngeal nerve can be freed more precisely or a decision made to divide it. Obviously the nerve should be conserved if possible, but if the only way to remove all nodal tissue involves resection of the nerve no hesitation should be felt in doing this. We have found it necessary in several cases. If nodes are so firmly adherent to the nerve that its division is necessary, paralysis by pressure would soon occur in any event. It may be argued that this indicates inoperability. Our experience does not support this view because long freedom from recurrence has followed this step. We used to think that pre-operative left recurrent laryngeal nerve paralysis was a sign of inoperability; it usually is and in most cases there are other features that confirm inoperability. In the absence of these other indications we would not now reject a case as unsuitable for exploration. There is certainly a phase in which the nerve is just involved by malignant nodes, but in which successful resection is still feasible. Moreover, we have had cases in which the involved nerve was resected and yet was not followed by loss of voice, indicating that compensation had already occurred for what was presumably a slow strangulation of the nerve. The clearance of the subaortic nodes should be pursued as far as possible under the aortic arch where, it will be remembered, they lie close to, or are in continuity with, the anterior tracheal group. The division of the ligamentum arteriosum makes this much easier and safer.

The ligamentum latum is now completely excised as on the right, and the clearance continued along the plane of the œsophagus to meet the original site of entry into the mediastinum behind the hilum. This exposes the posterior aspect of the pericardium covering the left atrium, and the pericardial incision is then extended to encircle the hilum and to meet the upper end of the first incision. The inferior tracheobronchial compartment is now widely exposed and can be cleared of its contents. At this stage also it is often possible to make a clearance of the anterior tracheal nodes which come into view. The final step is the division of the bronchus obliquely and immediately below the carina; the stump is sutured and covered with para-œsophageal mediastinal fascia, as already described. If, as part of the radical clearance, it has been necessary to resect the vagus nerve just below the aortic arch, there will be no fascial tissue to cover the bronchus; the cut

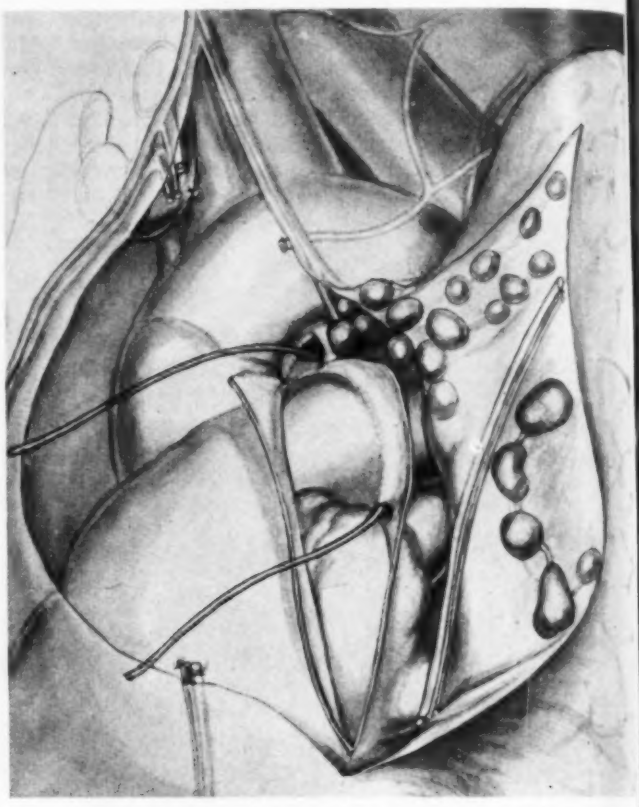


FIG. 23.—The left pulmonary artery has been exposed intrapericardially at its very origin. The first ligature has been passed medial to the ligamentum arteriosum; this is sometimes deliberately cut so as to aid dissection of the subaortic fossa.

end will in any case be deep within the mediastinum. It is sometimes possible to swing a pedicled flap of parapericardial fat to sew over the stump, or the cut edge of pericardium may be used.

THE EXCISED SPECIMEN

Figs. 25 and 26 show diagrammatically the extent of tissue removed by this radical technique, and *Figs.* 27 and 28 are photographs of a right and a left lung treated in this way. It will be seen that the block removal includes an oval of pericardium surrounding and protecting the hilar compartment and all the associated mediastinal areolar tissue and lymph-node groups.

After fixation these nodes are carefully dissected and their position marked on special charts (*Figs.* 29, 30); each node is numbered and half of it is removed and sent for histological examination. Some thirty to forty are usually examined. The resultant findings are then charted.

In this way it is possible to know whether a complete clearance has been made; whether there is early nodal involvement, or whether extensive invasion has occurred. By this technique it should

be possible, over a period of years, to ascertain whether the radical operation is successful in curing a higher proportion of cases than is possible by a lesser procedure.

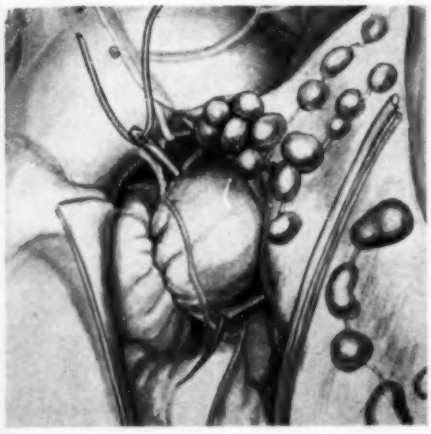


FIG. 24.—The first ligature has been tied around the pulmonary artery proximal to the ligamentum arteriosum; the second ligature is to be a transfixion one.

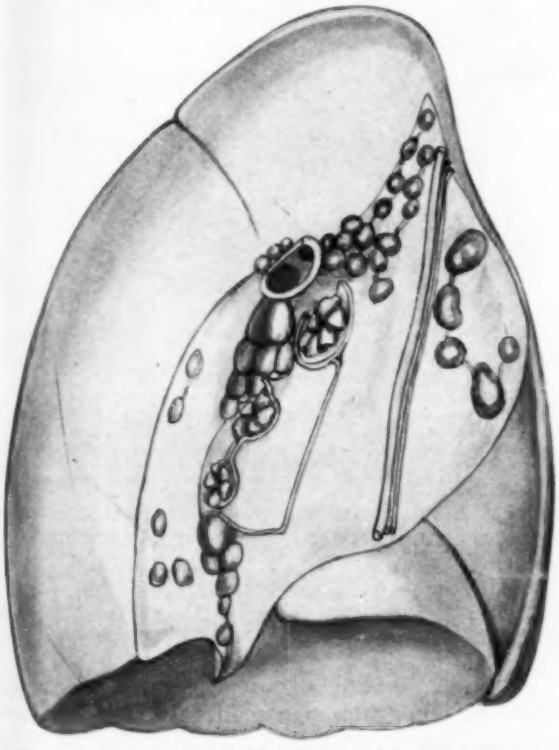


FIG. 25.—Diagram of right lung and associated lymphatic and other tissue excised at radical pneumonectomy.

DISCUSSION

It is clearly necessary to study many cases over many years before any authoritative pronouncement can be made on better results due to this operation. The results are intermingled with other features such as relative malignancy, the stage of advancement of the disease before operation, and the presence of independent distant metastases. It is, however, certain that the operation is soundly conceived in accordance with the accepted principle of radical cancer surgery.

One matter that can be answered at once is the risk of the procedure and whether it involves a higher immediate mortality. Our figures show conclusively that this is not so. Thus there were 16 deaths in 145 radical pneumonectomies, a mortality of 11 per cent; this compares favourably with world statistics of routine pneumonectomy for carcinoma. Sixty of these operations were done by ten other surgeons who were in various stages of training in the procedure.

Over the same period (1947–55), of these 145 radical operations, 49 simple pneumonectomies were done by the same group of surgeons; there were 9 deaths, a mortality of 18 per cent.

The radical operation is just as well tolerated as the less radical procedures and this is so even in patients in the late sixties, in several of whom it has been found to be the only way in which removal of the growth was even possible. In fact 26 patients were between 60 and 65 years and 7 were over 65 years; of these 33 cases, 5 died. Nevertheless, the radical operation, especially the wide opening of the pericardium, may be an extra burden in an elderly, poor-risk patient, and we have sometimes been content with a less radical removal. On the other hand, it must be emphasized that on many occasions it has only been possible to remove the growth by using this radical technique. This was so, for instance, in the case of a frail man who was

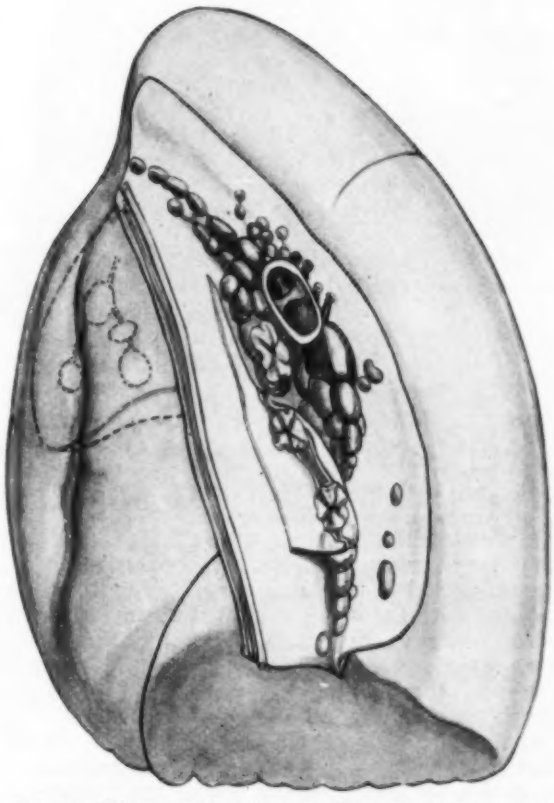


FIG. 26.—Diagram of the left lung and tissue excised at radical pneumonectomy.

a month or two more than 70 years of age and who bore the operation very well.

The only significant feature we have observed is a higher incidence of cardiac arrhythmias (atrial flutter, intermittent or continuous, atrial fibrillation, etc.) which may begin any time within two to fourteen days after operation. Except occasionally, this is little more than a clinical observation and usually soon responds to treatment. It may be due to the severity of the operation alone, for it occurs with many other intrathoracic operations. The apparent increased incidence suggests that it may be associated with the widespread interference with and ablation of the various cardiac nerves that inevitably occur. It is our practice to give pre-operative digitalis to all patients over the age of 50 years who undergo thoracotomy for any procedure.

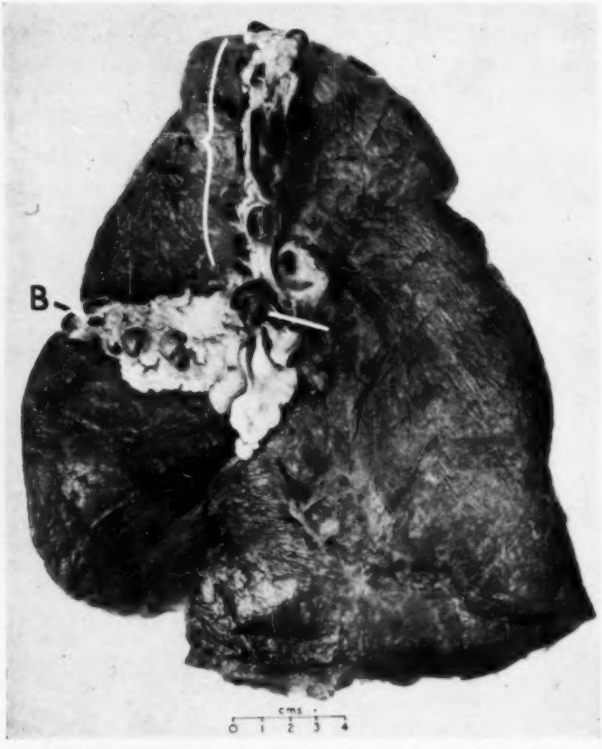


FIG. 27.—Photograph of a right lung removed by radical pneumonectomy, showing a cuff of pericardium and the mediastinal lymph-nodes removed *en bloc* with the lung. A, Right tracheobronchial nodes; B, Anterior mediastinal nodes; C, Inferior tracheobronchial nodes.

Although the operation may seem to be unduly severe it is, in fact, not so. The free exposure it gives makes for greater safety, speed, and confidence, and exactitude in performance. The securing of either the veins or the artery can be done safely and quickly, whereas in certain cases the ordinary hilar dissection would be difficult, dangerous, or even impossible, and would involve a much longer and more exacting dissection.

It may be objected that an extensive radical operation of this nature is often not justified in the presence of advanced malignant disease. This is a matter of surgical policy and philosophy that can only be answered by the individual surgeon. We believe that in dealing with a disease like cancer, especially cancer of the lung, bold and radical measures are both indicated and justified. This is not to say, of course, that foolish and desperate attempts are made to resect irremovable growths. There must be a balance of reason in all things; we merely feel that the surgeon should not turn away too readily from his task when a radical method is available that enables him to deal effectively with a wider range of cases.

That this policy is justified has been shown by a number of individual cases. Our first patient operated upon by the radical procedure in June, 1947, a man aged 43, seemed to be hopelessly inoperable. A large growth in the right upper lobe was complicated by a large malignant mass of lymph-nodes in the right tracheobronchial fossa; removal of these nodes entailed resection of the vagus nerve high up. The nodal involvement was proven histologically. This man is alive and well eight years later.

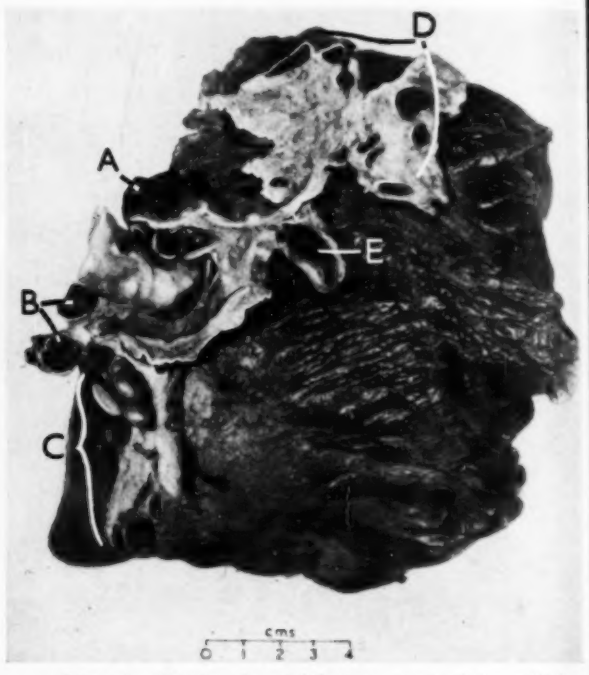


FIG. 28.—Photograph of left lung removed by radical pneumonectomy. A, Nodes of the recurrent loop; B, Inferior tracheobronchial nodes; C, Para-œsophageal nodes and nodes of the pulmonary ligament; D, Anterior mediastinal nodes; E, Node of ligamentum arteriosum (turned down).

Again, in January, 1948, we performed a radical pneumonectomy on a man aged 50 in whom a large malignant mass in the right upper lobe was associated with gross enlargement of all the nodes in the right tracheobronchial fossa. A complete clearance was made with considerable difficulty owing especially to the way in which the fascial planes over the superior vena cava were obliterated and adherent. The vein itself was narrowed. This is the type of growth in which superior vena caval obstruction rapidly supervenes, often with intense suffering and always with early death. We felt that an attempt at radical removal was justified. The vagus nerve had to be included in the block dissection from the level of the superior thoracic inlet downwards.

Examination of the excised specimen and its nodes showed an anaplastic carcinoma with extensive glandular invasion. After operation a course of deep X-ray therapy was given by Professor Waldron Smithers.

This patient remained well and working full-time for three years after operation. In September, 1949, a small hard node was felt above both clavicles and deep X-ray therapy was given to both sides of the neck; the nodes disappeared. Unfortunately, month after operation, when she noticed a painful lump in the 4th right rib which was obviously a metastasis. Hepatic metastases later appeared and she died in March, 1954, nearly six years after operation.

In this case the radical clearance included at least one malignant node that would otherwise have been left behind, and perhaps other involved ones

FIG. 29.—Charts which are used to record the site of the nodes dissected and examined histologically; they show anteroposterior and lateral projections on to the mediastinum of the lymph-nodes removed *en bloc* with the right lung from the specimen shown in *Fig.* 27. The dotted line on the lateral diagram indicates the area of mediastinal pleura and pericardium excised. A G, Anterior mediastinal nodes; H–L, Inferior tracheobronchial nodes; M–Q, Nodes intermediate between the inferior tracheobronchial group and the right tracheobronchial chain; R, Nodes of the azygos arch; S–Z, α and β, Right tracheobronchial nodes.

secondary deposits appeared in various bones and, in spite of irradiation, death occurred in June, 1951, three and a half years after operation. This patient died of his malignant disease, but he obtained three extra and very valuable years of useful life, free from any symptoms, and the radical operation therefore justified itself.

It will be noted that the metastases that finally killed him were distant blood-borne ones and this has been so in many patients who have had recurrence after a radical clearance. Thus a woman, aged 49, underwent a right radical pneumonectomy in June, 1948, for an anaplastic carcinoma of the right lower lobe. Clearance of the lymph-node groups was difficult because they contained many enlarged nodes which were very adherent. Out of sixteen mediastinal nodes examined histologically, only one contained growth, and that was in the inferior tracheobronchial group; one broncho-pulmonary node was invaded. She remained perfectly well until July, 1953, just five years and one

even though they were not identified histologically. It seems certain that she was spared early recurrence by the radical clearance.

Histological examination of the nodes in the excised specimen was carried out according to the plan in *Figs.* 29 and 30 in almost every instance,

Table I.—RADICAL PNEUMONECTOMY

Total cases	145
Died	16 (11 per cent)
Survived operation	129
Died since operation	57
Still alive	72

and the results are available in 115 cases. Unfortunately, owing to a mishap, the findings in a number of other cases were destroyed and are not available. However, certain valuable observations and deductions can be made from these examinations. It is realized that histological examination of lymph-nodes is not necessarily conclusive of their freedom from involvement. It is clearly possible to

miss small or early metastases unless serial sections are made from each node; this is virtually impracticable.

The results in the 145 radical cases are given in *Table I.*

In contrast are the results in the group of 49 simple pneumonectomies done over the same period. (*Table II.*)

Table II.—SIMPLE PNEUMONECTOMY

Total cases	49
Died	9 (18 per cent)
Survived operation	40
Died since operation	31
Still alive	9

Thus only 18 per cent of the patients who underwent simple pneumonectomy are alive, whereas 50 per cent of the radical pneumonectomy patients are alive.

These figures can be further analysed. (*Table III.*)

It is to be noted that the lymphatic nodes were invaded with growth in all of the long-survival patients and it is not unreasonable to assume that

Table III.—RADICAL PNEUMONECTOMY

Died since operation, 57

SURVIVED	NO. OF CASES	STATE OF GLANDS
5 years and over	1	+
4 years and over	1	+
3 years and over	2	+
2 years and over	7	3+, 2−, and 2 not examined
1 year and over	20	10+, 7−, 3 not examined
6 months and over	12	6+, 6−
Under 6 months	14	7+, 7−, 2 not examined

the life of these patients was genuinely prolonged by the radical clearance more than it would have been if the nodes had not been systematically removed. It is interesting to note that in the shorter survival cases the incidence of nodes involved with growth and free from growth was approximately equal, suggesting that blood-borne metastases and the inherent malignancy of the process were responsible for death.

Table IV gives the patients who are still alive after radical operation.

Table IV.—RADICAL PNEUMONECTOMY

Still alive, 72

ALIVE	NO. OF CASES	STATE OF LYMPH-NODES
7 years and over	5	4−
6 years and over	3	3−
5 years and over	7	4−, 3 not examined
4 years and over	14	1+, 6−, 5 not examined
3 years and over	6	5+, 1−
2 years and over	17	2+, 15−
1 year and over	15	1+, 11−, 3 not examined
Under 1 year	5	2+, 2−, 1 not examined

The same analysis in the simple pneumonectomies is shown in *Table V.*

The much higher and earlier mortality is evident. It is especially worthy of comment that in the case of the patient surviving over seven years a large malignant node was detected in the subaortic fossa after the lung had been removed; this node was excised and it was necessary to resect the recurrent laryngeal nerve with it. Had it not been removed it is certain that he would not have survived seven years.

Table VI shows the duration of life in the nine survivors of simple pneumonectomy.

It should be noted that 6 patients are still alive and well five years and more after operation. It would appear that long survival after a simple pneumonectomy is chiefly decided by the basic

Table V.—SIMPLE PNEUMONECTOMY

Died since operation	31
Survived	
7 years and over	1
3 years and over	1
2 years and over	2
1 year and over	8
6–12 months	9
Under 6 months	10

biological malignancy of the growth, with the exception of those rare cases in which operation is done so early that there has been no time for metastases to occur even though the growth happens to be of high malignancy.

The number of cases presented is relatively small, and concomitant variables are doubtless so numerous that it is difficult to draw any firm conclusions from them. However, it seems not unreasonable to say that the figures afford strong evidence that radical pneumonectomy gives better results than simple pneumonectomy.

Radical Pneumonectomy and Deep X-ray Therapy.—We have used deep X-ray therapy *after* pneumonectomy in only a few cases, partly because radiation, if strong enough to be effective, upsets

Table VI.—SIMPLE PNEUMONECTOMY

Still alive	9
Duration	
8 years and over	3
6 years and over	1
5 years and over	2
4 years and over	1
3 years and over	1
2 years and over	1

the patient very much, usually more than the operation itself. Also it has been felt desirable to study the results of operative treatment alone, except in those cases in which it would seem improper to withhold the possible additional benefits that deep irradiation may offer. An example of this was mentioned earlier.

In contrast, a problem that occasionally arises is that of removal of the lung after irradiation for an apparently inoperable growth. In 4 such cases distant metastases occurred fairly soon after the course of deep X rays had been concluded and before pneumonectomy could be done. A fifth, previously inoperable case with paralysis of the phrenic nerve, was explored three months after irradiation; radical pneumonectomy was only possible with partial resection of the superior vena cava; the patient died some two weeks later. In a sixth case, however, the result was sufficiently significant to be reported :—

A woman, aged 28, after a short illness, was found in January, 1949, to have a large growth of the right upper lobe. The condition was revealed to be quite inoperable at bronchoscopic examination owing to the level of infiltration of the right main bronchus and compression and distortion of the lower end of the trachea and of both main bronchi by enlargement of the three adjacent groups of lymphatic nodes. Biopsy revealed an oat-celled carcinoma.

She was given a full course of deep X-ray therapy by Professor Smithers, who later referred her back for reassessment. Bronchoscopy now revealed that the bronchi were no longer compressed and deformed. The chest was explored in July, 1949, and a radical operation was found to be possible. When examined after removal the primary growth was yellowish and necrotic looking and several of the excised nodes contained similar necrotic tissue. None of the nodes showed active growth. She is still alive and well nearly six years after operation and over six years after first coming for advice.

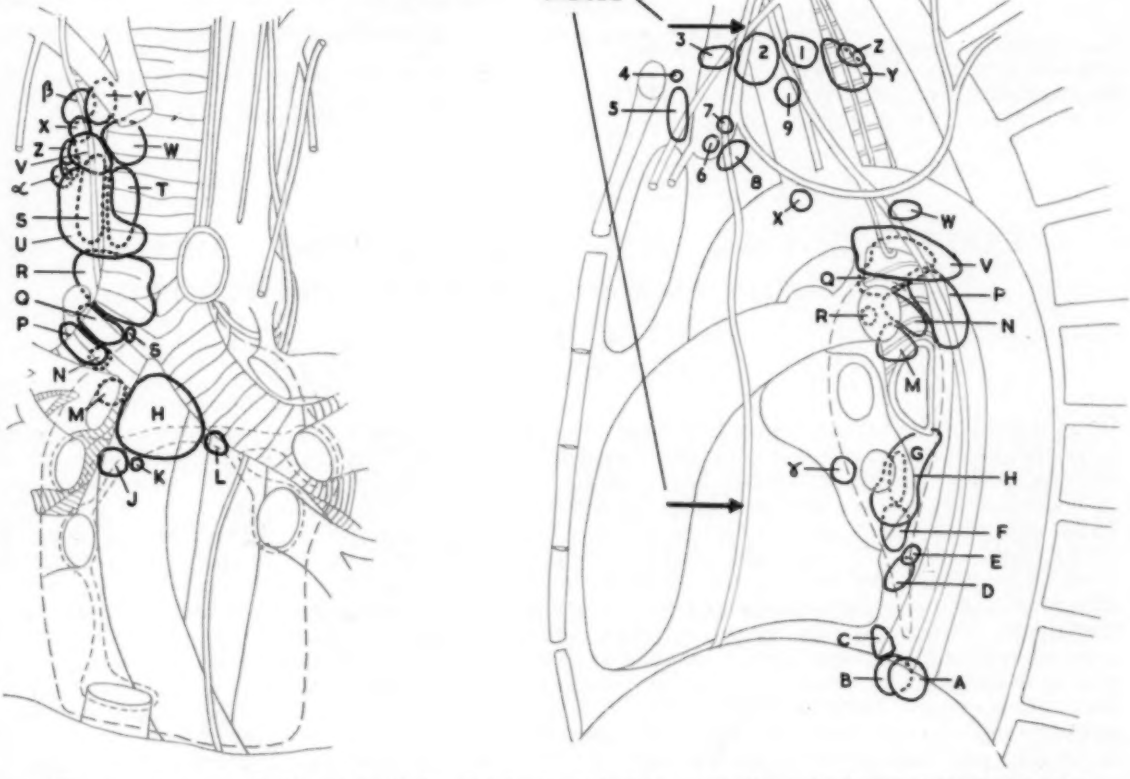


FIG. 30.—Charts used to record the anteroposterior and lateral projections on to the mediastinum of the lymph-nodes removed *en bloc* with the left lung from the specimen shown in *Fig.* 28. A–H and γ, Para-œsophageal nodes and nodes of the pulmonary ligament; J, K, and B, Inferior tracheobronchial nodes; L, M, and S–U, Hilar nodes; N–Q, Nodes of the recurrent loop (lower members of the left tracheobronchial chain); R, Node intermediate between inferior tracheobronchial group and the left tracheobronchial chain; V, Node of the ligamentum arteriosum; W, X, and 1–9, Anterior mediastinal nodes; Y, Z, Left tracheobronchial nodes.

SUMMARY

The history of lung resection is briefly outlined and the gradual evolution of radical pneumonectomy for bronchial carcinoma is detailed. This operation is in keeping with the generally accepted principles of cancer surgery elsewhere—namely, removal of the affected organ, its fascial connexions, and lymphatic field in one block.

The importance is emphasized of routinely securing the pulmonary artery and vein at their very origin, within the pericardium. A common mode of spread of carcinoma is along these vessels; this being so, it is clear that the hilar compartment should not be touched at operation. It is for this reason that intrapericardial ligation should always be done with resection of an oval of pericardium surrounding the hilar structures.

The technical details of the radical operation on each side are fully described.

The operation was designed and first performed in June, 1947; since then 145 radical operations have been done.

In this period 49 simple pneumonectomies for carcinoma have been done by the same surgical group.

The results in these two sets of cases are presented.

The mortality in the cases of radical pneumonectomy was 11 per cent; that of simple pneumonectomy was 18 per cent. The radical operation is not more dangerous than lesser procedures.

Only 9 (18 per cent) of the simple pneumonectomy patients are still alive; 72 (50 per cent) of the radical pneumonectomy patients are alive.

A method of charting and examining the lymph-nodes removed in the radical operation is described

and certain deductions are made from a study of the findings.

It is concluded that radical pneumonectomy is, in theory, a sound operation for bronchial carcinoma and in practice, over an eight-year period, has shown itself to be fully satisfactory and to give a higher percentage of cures.

Acknowledgement.—*Figs.* 10, 11 are reproduced by kind permission of Masson et Cie, publishers of *Anatomie des Lymphatiques de l'Homme*, by Rouvière.

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EARLY POST-CIBAL SYMPTOMS FOLLOWING GASTRECTOMY*

AETIOLOGICAL FACTORS, TREATMENT AND PREVENTION

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IN approaching the immense world literature on the early post-cibal syndromes it is abundantly clear that there is hardly a single fact about the incidence or pathogenesis on which there is general agreement. In an attempt to collect reliable data on some of the controversial issues, and especially to obtain British views on the subject, we sent a questionnaire to some fifty physicians and surgeons whom we knew to be particularly interested in gastric surgery. We received replies from many and are grateful to those who devoted so much time and care to their preparation. This paper is based on these replies, on recent publications, and on our own data. In spite of apparently contradictory evidence on many points, we believe that certain fairly definite conclusions can be drawn and some widely held views can be refuted.

Definition of Terms.—We recognize two main types of *early* post-cibal syndrome, each of which may appear while eating or a few minutes after :—

1. '*Dumping Syndrome*' proper, in which a feeling of epigastric fullness, distension, or 'pressure' is accompanied by one or more of the following symptoms : Drowsiness, fatigue and muscular weakness, palpitations, and sweating and a sensation of warmth. Nausea, colic, borborygmi, and diarrhœa may also be present, but we do not regard them as pathognomonic. Nor do we regard fullness alone as constituting the syndrome (Muir, 1949 ; Goligher and Riley, 1952 ; Butler, 1952).

2. '*Bilious Vomiting*', in which regurgitation or frank vomiting of bile, unaccompanied by food, is the main feature. It may occur daily or in episodes at longer intervals. Dumping symptoms are sometimes experienced at the same time and may be relieved by voiding the bile. Sometimes dumping symptoms, which increase gradually, are present for twenty-four hours or more and are relieved by the bilious vomit. Most British surgeons regard this bilious vomiting as something separate from the 'dumping syndrome' proper, and it may be more troublesome (Wells and Welbourn, 1951 ; Wells and McPhee, 1952 ; Pulvertaft, 1952). This view has received little support from workers in other countries, but Hoffman (1952), Roux, Pedoussault, and Marchal (1950), and Steinberg (1949) should be mentioned.

Length of Time after Operation.—It is generally agreed that early post-cibal symptoms improve spontaneously for the first year or two after operation. Mercer (1954), who investigated this point carefully, found that half of those who suffered from dumping symptoms immediately after operation lost them within eighteen months and one-third of those who regurgitated or vomited bile ceased to do so within twelve months. After this the incidence remained constant up to four years after operation. We have found no appreciable change up to thirteen years (Welbourn, 1953), but Meurling (1953) found some improvement after about ten years. We have seen a few patients whose post-cibal symptoms, especially bilious vomiting, have recurred, or in whom they have developed for the first time several years after operation. MacPhee (1954) has also encountered such patients.

AETIOLOGICAL FACTORS

These may be divided into two main groups: (1) Factors apparent in the general clinical picture;

* Based on two papers presented by the authors on behalf of the British Society of Gastroenterology at the International Congress of Gastroenterology in Paris, June, 1954.

and (2) Factors which depend on the mechanics of the operative procedure itself.

1. Factors apparent in the General Clinical Picture.—

a. Age, Length of History, and Severity of Symptoms.—It is often said that the worst functional results are obtained in young people who have not suffered severely or long before they came to operation. We have examined the evidence for this statement and can find little to support it. Butler (1952), Pulvertaft (1952), and Meurling (1953), for instance, found that *age* had no significant effect on the incidence of dumping symptoms or bilious vomiting, and Tanner (1954, a) speaks of the " exceptionally good progress " of the few patients aged 20 to 30 on whom he has performed gastrectomy for intractable ulcer. We agree with Muir (1949) that the *duration of ulcer symptoms before operation* does not affect the incidence or severity of symptoms afterwards (*Table I*). It is probable that those who have lost much weight before operation *have suffered* more than those who have experienced none of these complications. However, we have been unable to find any evidence that this factor influences the functional result (*Table II*).

b. Site of Initial Lesion. Although some (Muir, 1949) have found that operations for gastric ulcer are less likely to be followed by functional disturbances than are operations for duodenal ulcer, the weight of evidence indicates that the site of the initial lesion does not affect the incidence of dumping symptoms or of bilious vomiting (Capper and Butler, 1951; Pulvertaft, 1952; Meurling, 1953; Moloney, 1954, a). Pulvertaft found that those with recurrent ulcers tended to have the worst symptoms, but this has not been our experience.

c. Severity of Lesion found at Operation.—Many (Tanner, 1954, a; Lauste, 1954) believe that the patient with a long history in whom a minimal lesion is found at operation is most liable to make much of his symptoms later. We have analysed (*Table III*) the incidence and severity of symptoms in relation to the severity of the lesion which was found at operation. Those with mild lesions (small ulcer or scar only) fared no worse than those with moderate lesions, but those with severe (large, very active, penetrating, or stenosing) lesions showed a much lower incidence of severe dumping symptoms and bilious vomiting than the others.

d. Sex.—Although Muir (1949), Capper and Butler (1951), and Brooke (1954) found no sex difference in the incidence of post-cibal symptoms, we agree with Perman (1935), Pulvertaft (1952), Meurling (1953), and Tanner (1954, b) that women, on the whole, fare rather worse than men (*Table IV*).

Table I.—Relation between Duration of Symptoms before Operation and Incidence and Severity of Symptoms 1–5 years after (Male and female combined)

(Welbourn's data)

Length of History (Years)	Total Number of Patients	Dumping Syndrome				Bilious Vomiting			
		Mild		Moderate and Severe		Mild		Moderate and Severe	
		No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
0– 5	35	13	(37)	5	(14)	3	(9)	1	(3)
6–10	30	15	(50)	4	(13)	0	(0)	4	(13)
11–20	24	11	(46)	4	(17)	2	(8)	3	(12)
21+	27	13	(48)	3	(11)	6	(22)	1	(4)

It is unlikely that the pre-operative duration of ulcer symptoms affects the incidence or severity of post-cibal symptoms after operation.

In order to save space, those having *no* symptoms are not recorded in this and subsequent tables. Their number is equal to the total number of patients minus the number having symptoms. They have been taken into account in the statistical analyses.

Table II.—Relation between Pre-operative Weight Change and Incidence and Severity of Symptoms after Operation (Male and female combined)

(Welbourn's data)

Pre-operative Weight Change	Total No. of Patients	Dumping Syndrome				Bilious Vomiting			
		Mild		Moderate and Severe		Mild		Moderate and Severe	
		No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
Lost or gained less than 15 lb.	101	33	(33)	7	(7)	10	(10)	8	(8)
Lost 15 lb. or more	71	19	(27)	7	(10)	12	(17)	5	(7)

It is unlikely that pre-operative loss of weight affects the incidence or severity of post-cibal symptoms.

2. Factors Depending on the Mechanics of the Operative Procedure.—

a. Extent of Gastric Resection.—Nearly all who replied to our questionnaire said that their impressions were that the incidence and severity of post-cibal symptoms varied with the extent of resection. The evidence, however, is inconclusive, perhaps because it is difficult to measure exactly the amount of stomach removed. More attention should be paid to devising a reliable method (Moore and Harkins, 1952; Johnson and Orr, 1954).

The evidence can be examined most readily by considering only anastomoses involving the jejunum. At one extreme is gastro-enterostomy in which a gastrojejunal anastomosis is made but in which no stomach is resected. Intermediate are various degrees of partial resection, while at the other extreme is total gastrectomy.

i. *Gastro-enterostomy* in the absence of recurrent ulceration undoubtedly produces an excellent functional result. Dumping symptoms and bilious vomiting have been described (Devine, 1940; Custer, Butt, and Waugh, 1946), but they are rare in our experience. Butler (1952) found dumping symptoms in only 3 per cent of cases following gastro-enterostomy (2 out of 73) compared with 14 per cent following partial gastrectomy (79 out of 558).*

ii. Following *partial gastrectomy* there is no clear evidence that dumping symptoms (*Table V*) or bilious vomiting (*Table VI*) are influenced by the extent of the resection. Pulvertaft (1954, b) found that, although dumping symptoms and bilious vomiting were not greatly influenced by the height of the resection, symptoms such as anorexia and nausea were much more frequent after the radical operations. Loss of weight is probably also greater in those who have undergone higher resections (Pulvertaft, 1952; Welbourn, 1953).

iii. It might be expected that *total gastrectomy* would result in the highest incidence of dumping symptoms. Goligher and Riley (1952) found that this was so, but Butler (1954) and Brain and Stammers (1951) found a *lower* incidence following total gastrectomy than they did after partial resection (*Table VII*). Our experience of total resections has been that they are more likely to be followed by complications such as colic, diarrhœa, and severe nutritional disturbances, especially megaloblastic anæmia, rather than by dumping symptoms or vomiting of bile. Most total resections are undertaken for carcinoma, and this factor may affect the post-operative symptoms. The data, however, are inconclusive and the subject requires further investigation.

Table III.—Relations between Severity of Lesion and Incidence and Severity of Post-operative Symptoms—Gastrojejunal Anastomosis

(Welbourn's data)

Severity of Lesion	Total No. of Patients	Dumping Syndrome				Bilious Vomiting			
		Mild		Moderate and Severe		Mild		Moderate and Severe	
		No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
Grade 1. Small ulcer or scar	21	6	(29)	4	(19)	1	(5)	3	(14)
Grade 2. Average lesion	40	8	(20)	8	(20)	6	(15)	5	(12)
Grade 3. Gross pathology	53	12	(23)	4[2]	(8)	4	(8)	1[1]	(2)

The results in males and females were very similar; the sexes have therefore been combined (*see Table IV*).

Statistical Analysis :—

[1] Comparing the incidence of moderate and severe bilious vomiting in Grade 3 lesions (1/53) with that in Grade 1 and 2 combined (8/61), Exact P (double tail) = 0·036.

[2] Comparing the incidence of moderate and severe dumping symptoms in the same groups, $\chi^2 = 3{\cdot}48$, P (1 D.F.) = < 0·1.

Those having gross pathology at the time of operation had less severe post-cibal symptoms than the others.

Table IV.—Effect of Sex on Incidence and Severity Symptoms after Operation (Dumping Syndrome and Bilious Vomiting Combined)

(Welbourn's data)

Sex	Total No. of Patients	Mild Symptoms		Moderate and Severe Symptoms	
		No.	Per cent	No.	Per cent
Male	154	44	(29)	23	(15)
Female	29	9	(31)	10	(34)

The severity of the initial lesions was similar in both sexes (*see Table III*).

Statistical Analysis: Comparing the incidence of moderate and severe symptoms in males with that in females, $\chi^2 = 6{\cdot}409$, P (1 D.F.) = < 0·02.

There is a higher incidence of severe symptoms in the females than in the males.

b. Type of Anastomosis.—

i. *Gastrojejunal anastomosis*: There has long been controversy over the relative merits of variations of the gastrojejunal anastomosis, i.e., whether antecolic or retrocolic, right-to-left, or left-to-right anastomosis is made, whether a small or full-width stoma is used, and whether a valve is incorporated or not. The arguments have mostly been theoretical

* Comparing the incidence of dumping symptoms in the two groups, $\chi^2 = 7{\cdot}3$, P (1 D.F.) = < 0·01.

and have borne little relation to the observed results. Few of those who replied to our questionnaire felt strongly that the type of anastomosis made much difference to the functional result, and most of those who have investigated the problem recently have found that the incidence of dumping and other symptoms after operation is about the same for all (Hosford, 1949; Capper and Butler, 1951; Goligher and Riley, 1952). It is clear that there is no *great* difference between the results of the various types and that none abolishes post-cibal symptoms completely, but in three respects the question cannot be regarded as completely closed: First, although most people have found no difference in the incidence of dumping symptoms between an antecolic and a retrocolic anastomosis, two recent observers (Meurling, 1953; Tanner, 1954, b) state that the antecolic is significantly better (*Table VII*). Secondly, the presence of a valve does not seem to affect the incidence of dumping symptoms (Hosford, 1949; Goligher and Riley, 1952; Meurling, 1953), but many believe that it reduces bilious vomiting (Hosford, 1949; Brooke, 1954; Orr, 1954; Tanner, 1954, b). We have not been able to find any conclusive evidence on this point. Thirdly, a Moynihan type of anastomosis (antecolic, afferent loop to greater curvature) has been found by Mimpriss and Birt (1948) and by Kellock (1954) to be particularly liable to cause dumping symptoms.* They believe that these result from the afferent loop reflux which is found so frequently after this procedure. There is, however, no clear connexion between reflux of food and the presence of post-cibal symptoms (Goligher and Riley, 1952), and some advocate the operation precisely because it allows better mixing of food with digestive juices (Lahey and Camblos, 1951; Pannett,

Table V.—Effect of Extent of Gastric Resection (Jejunal Anastomosis) on Incidence of Dumping Syndrome

Author	Extent of Resection								
	½–¾			¾–⅞			*Total Resection*		
	Total No. of Pts.	Dumping Symptoms No.	Dumping Symptoms Per cent	Total No. of Pts.	Dumping Symptoms No.	Dumping Symptoms Per cent	Total No. of Pts.	Dumping Symptoms No.	Dumping Symptoms Per cent
Goligher and Riley (1952)	52	23[1]	(44)	60	25[1]	(42)	14	10[1]	(71)
Pulvertaft (1952)	62	17	(27)	140	45	(32)			
Pulvertaft (1954, b)	51	9	(18)	144	44	(31)			
Johnson and Orr (1954)	232	37[2]	(16)	222	104[2]	(47)			
Brooke (1954)	74	7	(9)	57	9	(16)			
Brain and Stammers (1951)				16	4	(25)	17	2	(12)
Butler (1952, 1954)	558	79[3]	(14)				40	1[3]	(2·5)

Statistical Analysis :—
[1] Comparing the incidence in total and in partial (½–¾) resection, $\chi^2 = 4{\cdot}2$, P (1 D.F.) = <0·05.
[2] Comparing the incidence in the 2 groups, $\chi^2 = 50{\cdot}3$, P (1 D.F.) = <0·001.
[3] Comparing the incidence in the 2 groups, $\chi^2 = 4{\cdot}364$, P (1 D.F.) = <0·05.
The other differences are not significant.
There is some evidence that dumping symptoms are commoner following high partial gastrectomy than they are following lower resections. The effect of total gastrectomy is uncertain.

Table VI.—Effect of Extent of Gastric Resection on Incidence of Bilious Vomiting

Author	Year	Extent of Resection					
		½–¾			¾–⅞		
		Total	Bilious Vomiting No.	Bilious Vomiting Per cent	Total	Bilious vomiting No.	Bilious vomiting Per cent
Pulvertaft	(1952)	62	10	(16)	140	21	(15)
Pulvertaft	(1954, b)	51	12	(24)	144	33	(23)
Johnson and Orr	(1954)	232	36[1]	(15)	222	73[1]	(33)
Brooke	(1954)	79	20	(25)	60	14	(23)
McPhee	(1954)	34	3	(9)	311	52	(17)

Statistical Analysis :—
[1] Comparing the incidence in the two groups, $\chi^2 = 19{\cdot}3$, P (1 D.F.) = <0·001.
The other differences are not significant.
There is little evidence that the incidence of bilious vomiting is affected by the extent of the resection.

* The difference in Mimpriss's and Birt's series is statistically significant. Good results were found in only 18 out of 38 patients (47 per cent), compared with 104 out of 134 (77 per cent) in the other groups $\chi^2 = 11{\cdot}9$, P (1 D.F.) = <0·001.

1950; Morley, 1954; Orr, 1954; Ross, 1954). We (W. M. C.) have been pleased with it. Bilious vomiting seems to be no more serious than it is after other forms of anastomosis, but vomiting of food has been used widely in Britain in the belief that it causes fewer post-cibal symptoms and less disturbance of nutrition than a gastrojejunal anastomosis. There is no general agreement about this, however

Table VII.—INCIDENCE OF DUMPING SYMPTOMS AFTER GASTRIC RESECTION WITH ANTECOLIC AND WITH RETROCOLIC ANASTOMOSES

AUTHOR	YEAR	TOTAL NO. OF PTS.	ANTECOLIC DUMPING SYMPTOMS				TOTAL NO. OF PTS.	RETROCOLIC DUMPING SYMPTOMS			
			Mild		Moderate and Severe			Mild		Moderate and Severe	
			No.	Per cent	No.	Per cent		No.	Per cent	No.	Per cent
No difference											
Mimpriss and Birt	1948	113	19	(17)	6	(5)	21	4	(19)	1	(5)
Hosford	1949	99	29	(29)	1	(1)	79	16	(20)	4	(5)
Butler	1952	397	15	(4)	42	(11)	161	3	(2)	19	(12)
Antecolic better											
Meurling	1953	52	22[1]	(42)	4[1]	(8)	106	64[1]	(60)	12[1]	(11)
Tanner	1954, b	245	41	(17)	8[2]	(3)	168	41	(24)	13[2]	(8)

Statistical Analysis :—

[1] Comparing the total number having symptoms in the two groups (Antecolic 26/52 ; Retrocolic 76/106) $\chi^2 = 7{\cdot}24$, P (1 D.F.) $< 0{\cdot}01$.

[2] Comparing the number having moderate and severe symptoms in the two groups, $\chi^2 = 4{\cdot}21$, P (1 D.F.) $= < 0{\cdot}05$. The other differences are not significant.

There is some evidence that an antecolic anastomosis carries a lower incidence of dumping symptoms.

Table VIII.—INCIDENCE OF DUMPING SYMPTOMS AFTER GASTRIC RESECTIONS WITH GASTRODUODENAL AND GASTROJEJUNAL ANASTOMOSES

AUTHOR	YEAR	GASTRODUODENAL					GASTROJEJUNAL				
		Total No. of Pts.	*Dumping Symptoms*				*Total No. of Pts.*	*Dumping Symptoms*			
			Mild		Moderate and Severe			Mild		Moderate and Severe	
			No.	Per cent	No.	Per cent		No.	Per cent	No.	Per cent
Custer, Butt, and Waugh	1946	? 50	—	—	1	(2)	? 450	—	—	27	(6)
Mimpriss and Birt[1, 3]	1948	44	7	(16)	1	(2)	134	23	(17)	7	(5)
O'Neill	1950	22	4	(18)	0	(0)	120	21	(17)	6	(5)
Capper and Butler	1951	102	0	(0)	0	(0)	558	18	(3)	61	(11)
Ross and Meadows	1952	65	2	(3)	0	(0)	91	14	(15)	10	(11)
Meurling[3]	1953	77	39	(51)	5	(6)	101	53	(52)	10	(10)
Moore and others	1953	79	26	(33)	0	(0)	61	21	(34)	2	(3)
Johnson and Orr	1954	92	—	—	16	(17)	232	—	—	37	(16)
Moloney	1954, a	98	4	(4)	0	(0)	56	9	(16)	2	(4)
Mercer	1954	9	—	—	1	(11)	91	—	—	31	(34)
Brooke	1954	48	3	(6)	0	(0)	167	16	(10)	5	(3)
Goligher	1954	116	17	(15)	3	(3)	209	54	(26)	15	(7)
Hall (Pulvertaft)[3]	1954, b	12	1	(8)	2	(17)	144	24	(17)	20	(14)
Hosford[1, 2]	1949, 1954	56	2	(4)	2	(4)	178	44	(25)	5	(3)
Kennedy	1954	24	5	(21)	0	(0)	43	15	(35)	3	(7)
Tanner[3]	1954, b	95	18	(19)	4	(4)	245	41	(17)	8	(3)
Visick (Pulvertaft)[3]	1954, b	17	1	(6)	5	(29)	62	10	(16)	7	(11)
Weir	1954	33	8	(24)	1	(3)	410	80	(20)	13	(3)
Totals		1039	137	(15·4)[4]	41	(4·0)	3352	443	(15·9)[4]	269	(8·0)

[1] These may contain a few cases which are not strictly " dumpers ".

[2] These two alone show results which appear *much* worse for the B.I.s, but the numbers are small and the differences are not significant.

[3] In these series differences were found between different types of gastrojejunal anastomosis. The *best* type has been compared with the gastroduodenal anastomosis.

[4] In calculating these two percentages, the series in which no mild cases are reported are excluded.

Statistical Analysis :—

Comparing the number with severe dumping symptoms in the two groups, $\chi^2 = 19{\cdot}63$, P (1 D.F.) $= < 0{\cdot}001$.

Mild dumping symptoms occur with equal frequency in the two groups. Severe dumping symptoms are twice as common after a gastrojejunal anastomosis as they are after a gastroduodenal anastomosis.

mixed with bile, although rare, can be troublesome (Ogilvie, 1947; Wells and Welbourn, 1951). All these questions require further study.

ii. *Gastroduodenal anastomosis* : During the past two or three years the Billroth I (Péan) operation and many regard the operation as unsuitable in cases of duodenal ulcer. We have tried to discover in what respects the results of the operations differ and have collected comparative data from several sources.

The data concerning *the Dumping syndrome* are shown in *Table VIII*. Of the 18 series that we have analysed, 13 show results in favour of the Billroth I operation, although in several the difference is not striking. Four series show results slightly against the Billroth I, but in none is the difference significant. Pooling of the results from all the series shows that after both forms of anastomosis about 15 per cent of patients had mild dumping symptoms. Moderate and severe symptoms, however, were twice as common after a gastrojejunal as they were after a gastroduodenal anastomosis (8 per cent and 4 per cent respectively). This difference, although significant, is not striking and does not tell the whole story. In the first place the symptoms tend to be *less persistent* after the Billroth I procedure. Tanner (1954, b) found this to be so, even though in his figures the total incidence after the two procedures was about the same. Goligher (1954), who reported no difference six months after operation (Goligher

Table IX.—INCIDENCE OF BILIOUS VOMITING AFTER GASTRIC RESECTION WITH GASTRODUODENAL AND GASTROJEJUNAL ANASTOMOSES

Author	Year	Gastroduodenal					Gastrojejunal				
		Total No. of Pts.	*Bilious Vomiting*				*Total No. of Pts.*	*Bilious Vomiting*			
			Mild		Severe			Mild		Severe	
			No.	Per cent	No.	Per cent		No.	Per cent	No.	Per cent
Moloney	1954 a	98	6	(6)	0	(0)	56	11	(20)	0	(0)
Brooke	1954	48	0	(0)	0	(0)	167	32	(19)	13	(8)
Goligher	1954	116	5	(4)	0	(0)	209	30	(14)	6	(3)
Hall and Conyers (Pulvertaft)	1954, b	12	0	(0)	0	(0)	144	16	(11)	17	(12)
Hosford	1954	56	0	(0)	0	(0)	178	11	(6)	2	(1)
Johnson and Orr	1954	92	—	(—)	11	(12)	232	—	(—)	36	(16)
Kennedy	1954	24	0	(0)	0	(0)	43	12	(28)	5	(12)
MacPhee	1954	26	—	(—)	0	(0)	315	—	(—)	52	(16)
Visick (Pulvertaft)*	1954, b	17	2	(12)†	4	(24)	62	6	(10)	4	(6)
Totals		489	13[2]	(3·5)*	15[1]	(3·0)	1406	118[2]	(13·7)†	135[1]	(9·6)

* This is the only series which shows worse results following a gastroduodenal anastomosis. The numbers are small, and the difference is not significant.

† In calculating these two percentages the series in which no mild cases are reported are excluded.

Statistical Analysis :—

[1] Comparing the incidence of severe symptoms in the two groups, $\chi^2 = 21{\cdot}7$, P (1 D.F.) = <0·001.

[2] Comparing the incidence of mild symptoms in the two groups, $\chi^2 = 29{\cdot}4$, P (1 D.F.) = <0·001.

All degrees of bilious vomiting are about three times as common after a gastrojejunal anastomosis as they are after a gastroduodenal anastomosis.

Table X.—EFFECT OF TYPE OF ANASTOMOSIS ON RECURRENCE OF ULCERATION FOLLOWING GASTRECTOMY FOR DUODENAL ULCER

Author	Year	Estimated Extent of Resection	Gastroduodenal Anastomosis					Gastrojejunal Anastomosis				
			Total No. of Cases	*Recurrent Ulceration*				*Total No. of Cases*	*Recurrent Ulceration*			
				Proved		Suspected			Proved		Suspected	
				No.	Per cent	No.	Per cent		No.	Per cent	No.	Per cent
Resection of less than about 70 per cent of stomach:—		Per cent										
Wells and Brewer	1948	50	24	5	(21)	4	(17)	29	7	(24)	3	(10)
Ross and Meadows	1952	60	37	4	(11)	3	(8)	? 91	0	(0)	0	(0)
Meurling	1953	67	123	13	(10)	8	(6)	? 175	0	(0)	2	(1)
Pulvertaft	1952 and 1954, b	67	17	4	(23)	—	(—)	119	3	(3)	—	(—)
Moloney	1954, a, b	67	112	2	(2)	—	(—)	43	1	(2)	—	(—)
Johnson and Orr	1954	67	25	0	(0)	—	(—)	200	1	(½)	—	(—)
Brooke	1954	67	15	1	(7)	1	(7)	49	1	(½)	—	(½)
Total			353	29*	(8·2)	16	(4·5)	706	13*	(1·8)	6	(0·8)
Resection of 70 per cent or more of stomach:—												
Moore and others	1953	71	64	0	(0)	0	(0)	100	3	(3)	2	(2)
Goligher	1954	75	48	2	(4)	—	(—)	168	2	(1)	—	(—)
Brooke	1954	75	8	0	(0)	0	(0)	48	1	(½)	1	(½)
Kennedy	1954	75	8	0	(0)	0	(0)	38	0	(0)	1	(3)
Lowdon	1954	75	98	0	(0)	1	(1)	429	? 4	(1)	? 2	(½)
Total			226	2	(0·9)	1	(0·4)	783	10	(1·3)	6	(0·8)

* Statistical Analysis : Comparing the incidence of proved recurrence in the two groups, $\chi^2 = 25{\cdot}1$, P (1 D.F.) = <0·001.

When less than about 70 per cent of the stomach is resected for duodenal ulcer the recurrence rate is much higher following a gastroduodenal anastomosis (8 per cent) than it is following a gastrojejunal anastomosis (2 per cent). When more than 70 per cent is resected the recurrence rate is about 1 per cent following both types of anastomosis. No long-term results are available.

and Riley, 1952), found the results of the Billroth I operation considerably better after a year. Secondly, we are much impressed by the fact that dumping symptoms are often cured or improved following the conversion of a gastrojejunal to a gastroduodenal anastomosis (*see below*).

Bilious vomiting (*Table IX*) is rare after the Billroth I operation, and most observers found no severe case in their series. It is common after all types of gastrojejunal anastomosis, the reported incidence of severe cases varying from 1 per cent to 16 per cent. The Billroth I operation, however, is not entirely free from this complication, and in Visick's small series the incidence was very high. Pulvertaft (1952, 1954, b) and Orr (1954) have met troublesome cases. There is some evidence that it occurs most commonly in patients in whom it has not been possible fully to mobilize the first part of the duodenum.

In three *other respects* the Billroth I procedure appears to yield better functional results. First, loss of weight is less (Meurling, 1953; Moore, Schlosser, Stevenson, Harkins, and Olson, 1953; Moloney, 1954, a); second, digestion and absorption of food (especially fat) are better (Wollaeger, 1950; Welbourn, Hallenbeck, and Bollman 1953; Butler, Capper, and Naish, 1954); and last, colic and diarrhœa are less frequent (Bohmansson, 1926; Brooke, 1954).

Against these advantages of the Billroth I procedure must be set the *disadvantage of a higher recurrence rate* when the operation is undertaken for duodenal ulcer (*Table X*). When less than about 70 per cent of the stomach is resected at least 8 per cent of cases develop anastomotic ulcers. In the comparable series of gastrojejunal anastomoses which we have analysed the proved recurrence rate was only 2 per cent. We have not enough evidence to say what the recurrence rate will be when 70 per cent or more of the stomach is resected, because few long-term results are available. Vagotomy together with a limited (e.g., two-thirds) Billroth I resection appears to give adequate protection against ulceration without causing any increase in post-cibal symptoms (Johnson, 1954; Moloney, 1954, a).

TREATMENT OF POST-CIBAL SYMPTOMS BY MEDICAL MEANS

It is generally agreed that minor post-cibal symptoms can be largely controlled by explanation, reassurance, posture, and dietary care. In the first instance careful analysis must be made to discover whether any specific foodstuff brings on symptoms. Sometimes milk or milky foods will initiate them and sometimes sweet things such as chocolate or sweet tea. It is wise to avoid food taken in liquid form, to take all meals dry, and to drink only between meals. Attention should be drawn to the important observation of Butler (Butler and Capper, 1951) that lying down for half an hour *before* a meal will often reduce the severity of bilious vomiting and allow the patients to eat larger meals in comfort. Lying down *during* a meal greatly reduces dumping.

Many drugs have been used in the treatment of *dumping symptoms*, but they have proved disappointing (Meurling, 1953; Rauch and Bieter, 1953). We shall comment briefly on four:—

1. Hexamethonium Bromide. — This was originally tried with the object of blocking afferent nervous impulses through the sympathetic ganglia (Glazebrook and Welbourn, 1952). It has been found effective in some cases when injected, but disappointing when given by mouth (Glazebrook and Welbourn, 1952; Smith, Fraser, Staynes, and Willcox, 1953; Kay, 1954; Pulvertaft, 1954, a), possibly owing to irregular absorption. It delays gastric emptying and reduces jejunal activity, and it may be that these are its main effects.

2. Potassium Salts.—These were given by Smith (Smith, 1951; Smith and others, 1953) with the object of preventing the feeling of weakness which they believed to be caused by hypokalæmia. They found it effective when given intravenously or orally, but the effect has not been confirmed and we (R. B. W.) have found no benefit from giving it by mouth. Recent observers (Pulvertaft, 1954, a; Munck, 1954) have not been able to confirm Smith's experimental findings.

3. Oral Local Anæsthetics.—Meurling (1948) found that procaine hydrochloride, given in an aqueous solution by mouth before eating, was often effective, but we (R. B. W.) have not found it so. A more powerful surface anæsthetic with a high viscosity and low surface tension ('xylocaine viscous' 10–15 ml.) is said to be more reliable (von Dardel and Morales, 1951). Kay (1954) has found it effective in one-third of cases and regards it as probably the best medical measure.

4. Sodium Bicarbonate. — Glazebrook and Wrigley (1952) found that dumping symptoms and hyperperistalsis, induced by a hypertonic glucose and barium meal, were greatly alleviated by adding 4 g. of sodium bicarbonate to the mixture. We (W. M. C.) have found it sometimes effective clinically when given by mouth before meals.

Bilious vomiting is even more refractory to medical measures, but Pulvertaft (1954, b) has found improvement in about half his patients after giving olive oil or 'Felevac' 20 to 30 minutes before meals.

Paravertebral Injection of Procaine Hydrochloride.—Various workers (Meurling, 1953) have attempted to block the afferent nervous pathways, which are thought to be involved in the dumping syndrome, by means of paravertebral injections. The first to do this was Butler (Butler and Capper, 1951), who performed bilateral blocks on 61 patients; 50 of these obtained complete relief of their symptoms and were able to eat normal meals in complete comfort. In the majority the relief lasted a few days only, but in 4 the effect appeared to be permanent, no symptoms having returned after several months. Eleven patients obtained no benefit from the injection. Butler controlled his experiment by injecting distilled water in 8 cases without effect. Meurling (1953) carried the experiment a step further by injecting 40–50 ml. of procaine subcutaneously *into the thigh* in 10 patients. Two of these were totally relieved, one apparently permanently; 4 had relief for a short time and 4 were unaffected. Roux and others (1950) report temporary relief of bilious vomiting following right-sided paravertebral injection.

It is clear that temporary relief can be obtained in many patients by injection of procaine, but it is not

clear how it exerts its effect. It is certainly worth a trial before undertaking any operative procedure, and its effect may occasionally be permanent.

TREATMENT AND ATTEMPTED PREVENTION OF POST-CIBAL SYMPTOMS BY SURGICAL MEASURES

Since spontaneous improvement in both dumping symptoms and bilious vomiting usually occurs during the first twelve to eighteen months after gastrectomy, medical measures should be continued for at least this period. Concomitant conditions, such as anæmia and vitamin-B deficiencies (Welbourn, Hughes, and Wells, 1951), should be corrected and other causes for the symptoms, such as stomal ulcer, cholecystitis, hiatus hernia, and carcinoma, should be sought, particularly if the syndromes have atypical features. When it is clear that improvement is no longer occurring, those few patients who continue to suffer *serious* disability should be offered the chance of relief by further surgery. It must be emphasized that surgery should only be undertaken when the following criteria have been fulfilled :—

1. Symptoms must be severe and disabling ;
2. At least eighteen months must have elapsed since the first operation ;
3. Other possible causes of the symptoms must have been excluded ;
4. Medical measures, and particularly sympathetic procaine block, must have been tried and failed.

Many surgical procedures have been advocated and used, but few surgeons have experience of any large number of cases. We have collected information abou the results of these secondary operations in 219 cases, and shall consider the more important procedures in turn (*Table XI*). Each procedure has also been used as a primary measure in order to prevent the development of post-cibal symptoms, and we shall discuss this aspect briefly.

There have been three main approaches to the problem (*Fig.* 31) :—

1. Modification of the Afferent Loop.—The afferent loop has been modified with the object of preventing bilious vomiting by allowing bile and pancreatic juice to flow freely into the efferent jejunal loop.

a. Entero-anastomosis.—An anastomosis between the afferent and efferent jejunal loops was used by Illingworth (Muir, 1949) in the treatment of 3 cases of severe bilious vomiting. The results were excellent and the procedure has since been used occasionally by others. The immediate results have been good in 38 out of 44 cases (86 per cent). Others (Morley, 1954 ; Orr, 1954) report favourably without giving details. The bilious vomiting is usually relieved or greatly diminished, but dumping symptoms (when they are present also) are relieved to a much smaller extent (Schofield and Anderson, 1953). In some cases the immediate improvement has not been maintained, and after a year or so the symptoms have been as bad as ever. No proved case of stomal ulcer has yet been encountered after this procedure, although one has been suspected (Johnson, 1954).

Entero-anastomosis has been performed by some at the same time as the gastrectomy with the object of preventing symptoms (Meurling, 1953 ; Pulvertaft, 1954, b). Neither dumping symptoms nor bilious vomiting were any less common than in cases without a short-circuit, and the incidence of recurrent ulceration was doubled.

b. Jejunoplasty.—This modification of Steinberg's (1949) ' pantaloon's ' anastomosis was developed independently by Hoag and Saunders (1941) and by Wells and Welbourn (1951) as a secondary operation for the relief of bilious vomiting. The results

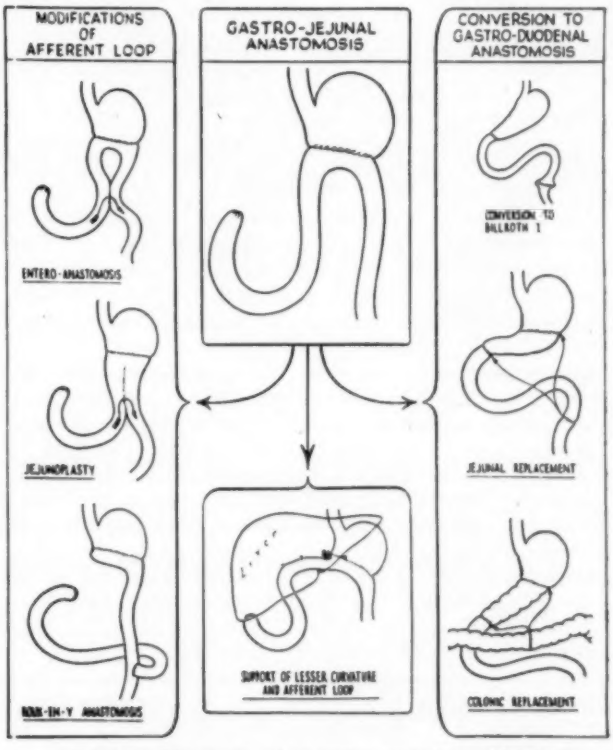

FIG. 31.—The types of operative procedure which have been used for the relief of post-cibal symptoms following gastrectomy with a gastrojejunal anastomosis.

have been very similar to those following entero-anastomosis (*Table XI*), 27 out of 31 patients (87 per cent) obtaining good immediate results. Others (Maingot, 1954) have reported favourably without giving details. The late results, however, have not been so good, and several patients have relapsed after a year or so (MacPhee, 1954). There has been one possible stomal ulcer (MacPhee, 1954). Troublesome post-operative bleeding at the suture line has been encountered by Wells (1954) and by one of us (R. B. W.) and care must be taken to secure complete hæmostasis. When performed as a primary procedure the ' pantaloon's ' anastomosis has *not* been found to reduce the incidence of bilious vomiting (MacPhee, 1954).

c. Roux-en-Y Anastomosis.—This operation has been used in two centres in Britain. Schofield (Schofield and Anderson, 1953 ; Schofield, 1954, a, b) reports excellent results in 13 cases and notes that vasomotor (dumping) symptoms, which were present in 5, were also relieved. Conyers and Hall (Pulvertaft, 1954, b) report good immediate results in 14 out of 15 cases, but find that the results after

Table XI.—Results of Operations for Post-cibal Symptoms

Surgeon	Year	Total Number of Cases	Number showing Early Improvement	Number Relapsed Later
Entero-anastomosis (for bilious vomiting) : —				
Bennett-Jones	1954	1	1	—
Brooke	1954	3	3	—
Conyers and Visick (Pulvertaft)	1954, b	15	13	9
Fraser	1954	1	1	1
Illingworth (Kay)	1954	9	8	—
Johnson	1954	1	1	—
Mimpriss	1954	1	1	(1 partly)
Rodgers (Mercer)	1954	1	1	—
Schofield (and Anderson)	1953 and 1954, a, b	7	7	2
Tanner	1954, b	4	1	—
Truscott	1954	1	1	—
Total		44	38 (86 per cent)	12 (+1)
Jejunoplasty (for bilious vomiting) : —				
Capper	1954*	1	0	—
Johnson	1954	2	2	—
Kennedy	1954	1	1	1
Lauste	1954	1	0	—
Tanner	1954, b	2	2	—
Welbourn	1954	8	8	—
Wells (MacPhee)	1954	16	14	5
Total		31	27 (87 per cent)	6
Roux-en-Y anastomosis (for bilious vomiting) : —				
Conyers and Hall (Pulvertaft)	1954, b	15	14	2 (+2 partly)
Schofield (and Anderson)	1953 and 1954, a, b	13	13	—
Total		28	27 (96 per cent)	2 (+2)
Support of lesser curvature and afferent loop (for dumping syndrome) : —				
Capper	1954*	9	8	—
Johnson	1954	2	2	—
Tanner	1954, b	3	1	1
Total		14	11 (79 per cent)	1
Conversion to Billroth I or Von Harberer (for bilious vomiting, dumping syndrome, malnutrition, etc.) : —				
Brooke	1954	4	4	—
Capper	1954*	5	4	—
Goligher	1954	2	2	—
Handley	1954	3	2	—
Illingworth (Kay)	1954	2	0	—
Johnson	1954	3	3	—
Kennedy	1954	3	3	—
Lavery	1954	1	1	—
Lowdon	1954	2	2	—
Murphy and Kindersley	1954	6	6	—
Porter	1954	6	6	—
Shepherd (MacPhee)	1954	1	0	—
Tanner	1954, b	21	18	—
Welbourn	1954*	4	2	—
Total		63	53 (84 per cent)	? 0
Jejunal replacement (for bilious vomiting, dumping syndrome, malnutrition, etc.) : —				
Capper	1954*	1	1	—
Henley	1953	5	5	—
Johnson	1954	1	1	—
Ross	1954	2	2	—
Total		9	9 (100 per cent)	—
Colonic replacement (for bilious vomiting, dumping syndrome, malnutrition, etc.) : —				
Moloney	1953, 1954	25	22	—
Wells (MacPhee)	1954	5	2	—
Total		30	24 (80 per cent)	? 0

* Presented in this paper for the first time.

a year or so are less satisfactory. Their patients were relieved of bilious vomiting, but not of dumping symptoms (Hall, 1954). No stomal ulcers have been reported in either series so far.

The operation has also been performed as a primary procedure by the same surgeons with the object of preventing post-cibal symptoms. Bilious vomiting does not occur, but there is the same disagreement about the occurrence of dumping symptoms as there is after its use as a secondary operation. It remains to be seen what the recurrence rate of ulceration will be.

2. Support of the Lesser Curvature and Afferent Loop.—This was undertaken as a secondary procedure for treatment of dumping symptoms proper (as opposed to bilious vomiting) by Capper and Butler (1951). It has not been used widely, but the available reports show immediate good results in 11 out of 14 patients (79 per cent). Orr (1954) also reports good results, but gives no details. Wells and MacPhee (1952) suggest that the main effect of the operation is the prevention of afferent-loop stasis.

When used as a primary procedure by Capper and Butler (1951) it reduced the incidence of dumping symptoms from 13 per cent to 1 per cent or 2 per cent,* but these results have not yet been confirmed. Lahey and Camblos (1951) claimed equally good results from a similar procedure, in which the anastomosis was made with the afferent loop to the *greater* curvature, but they had no control series.

3. Conversion to Gastroduodenal Anastomosis.—

a. Billroth I or von Haberer Technique.—Bohmansson (1950) and Perman (1947) reported excellent results following the conversion of gastrojejunal to gastroduodenal anastomoses in patients with various alimentary symptoms, including dumping, diarrhœa, steatorrhœa, anæmia, and loss of weight following gastro-enterostomy and gastrectomy. Their series are large (36 and 25 cases respectively) and their reports have attracted much interest. Sjögren (1952), who later reviewed Perman's cases, found that the men and women behaved differently. In the former the good functional results persisted, but anastomotic ulcers developed in 5 cases (23 per cent). In the latter about one-half were unimproved. Perman (1954) has now increased his series to 48 and reports very similar results.

Several British surgeons have operated on smaller series and have obtained good early results in 53 out of 63 cases (84 per cent). Bilious vomiting appears to be relieved more consistently than dumping symptoms, but the latter are certainly improved in many. The nutritional state is sometimes improved to a remarkable degree and steatorrhœa may be abolished (Naish and Capper, 1953). The most spectacular results are obtained in those who are cachectic and who have a gross excess of fat in the stools. There are not many late results, but Tanner's 21 cases have been followed for at least four years and remain well. No case of anastomotic ulcer has been encountered in this series, possibly because British surgeons tend to do higher resections than those in the Scandinavian countries. Bennett-Jones (1954) has performed Billroth I resections with good results in a few patients who have developed troublesome bilious vomiting after vagotomy and gastro-enterostomy.

As a primary procedure for *gastric* ulcer the Billroth I operation is the best operation available. Many recently have also used it for duodenal ulcer and have found it technically possible in well over half their cases, especially if the duodenum is mobilized and the anastomosis is made into its second part (Moore and others, 1953). We have already discussed its advantages and disadvantages and would stress that a final conclusion cannot be drawn until there is more information about the recurrence rate following high resections or low resections with simultaneous vagotomy.

b. Jejunal Replacement.—Henley (1952; 1953) has employed a jejunal implant for bridging the gap between the stomach and the duodenum when re-operating on patients with severe functional and nutritional disturbances following gastrectomies with gastrojejunal anastomoses. Excellent results are reported in 9 cases. When used as a primary procedure jejunal ulceration develops in a high proportion of cases (Jones, 1954; Maingot, 1954).

c. Colonic Replacement.—Moroney (1951; 1953; 1954) has developed a similar operation, but places a length of transverse colon between the gastric stump and the duodenum. He stresses the importance of a high gastrectomy or an added vagotomy before doing a colonic replacement if the previous operation had been for duodenal ulcer and particularly if free acid is found.

Maingot (1954) has found the operation effective, but Well's cases (MacPhee, 1954) have been disappointing and show a tendency to develop dilatation of the third part of the duodenum.

Moroney (1951; 1953) has used the operation extensively as a primary procedure and reports excellent results. Goligher (1954) was not impressed by the absence of dumping symptoms and encountered one stomal ulcer in a series of 12 cases. Maingot (1954), in a series of over 30 cases, has found the early results to be bad, but the later ones excellent, and has had no recurrent ulceration.

There are two things which must be said about both jejunal and colonic replacement. First, their functional results may compare favourably with those following resections with gastro*jejunal* anastomoses, but they have not been shown to be superior to those following a straightforward gastro*duodenal* anastomosis. Secondly, in average hands they must inevitably carry a higher operative mortality and immediate post-operative morbidity than simpler procedures, involving as they do three intestinal anastomoses. For these reasons alone we believe that they have no place in the *primary* surgical treatment of peptic ulceration.

Other surgical procedures, such as division of adhesions, narrowing of the stoma, reversal of the jejunal loops, vagotomy, and splanchnicectomy have all been used occasionally, but the results have been variable and no adequate series are available for analysis.

* The difference is highly significant. Comparing the incidence in the two groups (Support: 2/128; no support: 15/113), $\chi^2 = 12{\cdot}43$, P (1 D.F.) = $<0{\cdot}001$.

In the present state of our knowledge it would seem that conversion to a Billroth I type of anastomosis is the procedure of choice for the surgical treatment of all types of post-gastrectomy syndrome, where a gastrojejunal anastomosis is present. In the majority of cases it is a relatively simple procedure and more difficulty is encountered in mobilizing the gastric remnant than in freeing the duodenal stump. Occasionally it may be simpler and equally effective to anastomose one of the jejunal loops, already attached to the stomach, to the duodenum (Henley, 1952). Whatever procedure is used, it would be a wise precaution to perform a simultaneous vagotomy to reduce the danger of recurrent ulceration, especially when making a jejunal replacement. The rare cases of severe post-cibal symptoms following Billroth I anastomoses fortunately do fairly well with medical measures.

SUMMARY AND CONCLUSIONS

1. This communication is based largely on replies to a questionnaire sent to fifty British physicians and surgeons.

2. Two types of early post-cibal symptoms are considered—the dumping syndrome proper, and bilious vomiting.

3. Early post-cibal symptoms improve spontaneously during the first twelve to eighteen months after operation: after this the incidence remains constant.

4. Age and the site of the ulcer have no effect on the incidence of symptoms; those who have gross pathology at the time of operation tend to have less severe post-cibal symptoms. Women on the whole fare worse than men.

5. Symptoms are rare after gastro-enterostomy. After gastrectomy there is no clear evidence that their frequency or severity bears any relation to the amount of stomach resected.

6. An antecolic anastomosis possibly gives better results than a retrocolic. There is no evidence that a valve or the site of attachment of the afferent loop are significant.

7. A Billroth I anastomosis is becoming more popular in Great Britain. Post-cibal symptoms are less persistent and less severe after this procedure; loss of weight is less and colic and diarrhœa are also less frequent. The recurrence rate following the Billroth I procedure for duodenal ulcer is higher than it is following gastrojejunal anastomoses.

8. In the initial stages of treatment explanation and reassurance are important. Careful analysis of dietary habits is valuable. Milk, sweet things, and food in liquid form may be causative factors. Meals should be taken dry and drinks only between meals.

9. Lying down for half an hour before a meal greatly reduces bilious vomiting, and lying down to eat or for half an hour after food reduces dumping.

10. Local anæsthetics by mouth, hexamethonium bromide, and sodium bicarbonate, all before meals, may improve dumping symptoms. Bilateral paravertebral splanchnic block with procaine probably gives the greatest relief, which may be permanent.

11. Surgical measures to give relief should only be considered when symptoms are severe and disabling and have persisted for at least eighteen months after operation.

12. Entero-anastomosis, jejunoplasty, and Roux-en-Y anastomoses usually relieve bilious vomiting, but relapse is common. As a primary procedure the Roux-en-Y anastomosis prevents bilious vomiting. After any of these procedures constant watch must be kept for recurrent ulceration.

13. Support for the afferent loop and lesser curvature of the stomach may relieve or prevent dumping symptoms.

14. Conversion to a Billroth I anastomosis usually relieves bilious vomiting, dumping symptoms, and diarrhœa, causes increase in weight, and reduces fæcal fat loss. Jejunal and colonic replacement of the stomach give similar results, but jejunal ulceration is common after the former.

15. In the present state of our knowledge, conversion to a Billroth I is the procedure of choice for the surgical treatment of all types of post-gastrectomy symptoms where a gastrojejunal anastomosis is present. It should not be undertaken until all other non-operative measures have been tried.

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SOME REMARKS ON THE REPAIR OF FLEXOR TENDONS IN THE HAND, WITH PARTICULAR REFERENCE TO THE TECHNIQUE OF FREE GRAFTING

BY A. B. WATSON, BIRMINGHAM

RESULTS show that flexor tendon repair is worth while and yet so many surgeons still believe that these injuries are not worth the trouble of treatment. This unfortunate feeling is due, I think, to two main reasons :—

1. Often an unduly long time has to be spent in the repair of what at first seems to be quite a trivial injury.

2. The end results are assessed too soon.

The observations in the following article are based on a critical survey of 51 tendon repairs which are thought to have reached their final stage, and observations on many others. The results vary considerably from a perfectly functioning finger to perhaps just merely the stabilizing of a terminal interphalangeal joint without the ability to flex, and I found that they were difficult to classify because some which I felt were not very good were thought by the patient to be extremely good. Two of this type are illustrated in *Figs.* 36, 37. The total of 51 excludes 4 in one hand where sepsis caused a sloughing of the tendons, and I have mentioned this case later under the heading of ' Sepsis '.

For the purposes of treatment severed flexor tendons in the hands and digits are divided into four groups :—

1. Divisions in the palm.

2. Divisions of the flexor pollicis longus.

3. Division of the profundus only, within ½ in. of its attachment to the base of the terminal phalanx.

4. When both tendons are divided at any point within the digital sheath and when the profundus alone is divided at any point proximal to ½ in. from its attachment.

RESULTS

I have attempted to classify these as follows :—

1. Divisions in the palm :—

Normal	4
Very good	1
Improved	3

2. Flexor pollicis longus :—

a. Treated by direct suture :

Very good	5
Improved	2

b. Treated by free graft :

Very good	3

3. Simple attachments to profundus :—

Normal	5
Improved	5
Stiff joint but stable	1

4. Division of both tendons and replacement by free graft :—

Very good	8
Improved	7
Poor	2
Failed	2
Improved, but too early to assess final results	3

ORGANIZATION

This article is intended to deal primarily with exact technique, but I feel that first of all I ought to mention what I believe to be the correct procedure generally. Almost all these cases attend in the first instance at a casualty department, and I feel very definitely that they should not be dealt with in such a department unless the following conditions can be fulfilled at once.

1. The wound shall be of such a type that it will be sure to heal by first intention.

2. Facilities, including a main operating theatre and good anæsthesia, are available for the operation.

3. A surgeon who is regularly dealing with tendons is immediately available to do the operation personally.

So often these three criteria cannot be fulfilled and therefore, nearly every time, the routine procedure should be to deal with the wound alone, aiming at first-intention healing, and then to repair the tendon by a set operation at some appropriate future date.

1. Divisions in the Palm.—

There is no dispute here that direct end-to-end suture is the method to be employed. This is one of the regions where primary suture as soon after the accident as possible can be expected to give a good result, and I believe that this can be carried out as a primary measure if the facilities I have already mentioned are available.

The method which should be used is a criss-cross stitch, as described by Bunnell (1952), but without his ' pull-out ' ideas ; the suture material is braided stainless steel on atraumatic needles. The sublimis is not sutured but rather the ends are removed in order to try to eliminate adhesions which I have seen cause restriction of movement, particularly at the distal end. Immobilization for three weeks follows and the results on the whole are good.

2. Divisions of the Flexor Pollicis Longus.—

I have placed these in a category of their own, because I believe that this is the only tendon which can be sutured within its sheath and which will then give a good result. Notes of 10 cases, 7 of which were dealt with by direct end-to-end suture and 3 by a free tendon-graft, show that the results are good in all cases (*Figs.* 34, 35). The emphasis here is that the functional result is good although the actual measurement of flexion may be disappointing, and, as Kyle and Eyre-Brooke (1954) remark, it is probable that some of the good results in the thumb may be due to the fact that this digit is such an individual actor. My own practice here is to do a direct suture of this tendon if it has not retracted to such an extent as to make this a difficult procedure technically ; if it has, then I do not hesitate to do a tendon graft, providing the muscle belly is in good condition—that is, that it has not lost its elasticity. If it has, then I would not hesitate to use one of the sublimis tendons of another digit as the activator, although I have not yet found this to be the case. One further point with regard to tendon grafting in this region—we are always told that the digital sheath of the thumb extends from the base of the terminal phalanx to a point just above the wrist joint, and whereas this may be anatomically true I think it is unnecessary to attempt to place a free graft over this length ; now, when using a graft in this situation, I make the points of anchorage of the graft at the terminal phalanx and in the musculature of the thenar space, as this region is sufficiently free and the tendon-sheath there seems to be so thin as not to be a sheath within the functional meaning of the word.

3. Division of the Profundus only, within ½ in. of its Attachment to the Base of the Terminal Phalanx.—Most writers, including certainly Pulvertaft (1948), and Rank and Wakefield (1950, 1952), are agreed that where the profundus only is divided, direct end-to-end suture is the method of choice, but Wakefield does point out that the excursion of the profundus tendon is about 3½ cm. so that it is possible for the profundus to be divided at a point where the normal excursion would cause it to come through the division in the sublimis. I have made a personal rule that the division of the profundus must be within ½ in. of its attachment,

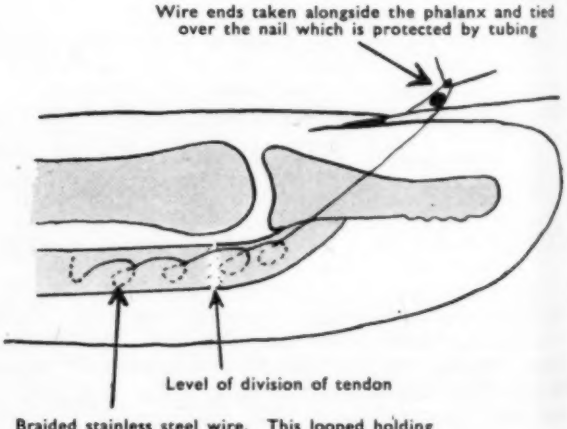
Wire ends taken alongside the phalanx and tied over the nail which is protected by tubing
Level of division of tendon
Braided stainless steel wire. This looped holding stitch is repeated on the other side.

Fig. 32.—Securing the tendon.

and then I know that any roughness caused by the junction will not interfere with the mechanism at the sublimis attachment. This is usually quite a simple procedure, and the method I have found most useful is to use a stainless steel wire which holds on both sides of the profundus tendon, as in the diagram, and then is taken out through either side of the nail and tied across the back of the nail (*Fig.* 32). This enables the proximal end to be

1. It is constantly present.
2. Its removal never causes any upset to the foot.
3. It is a small tendon and is therefore easily threaded through tunnels and holes and is easily attached to the proximal end of profundus.
4. Its small size makes no difference to the eventual function of the finger and one illustration given here has two such tendons in his hand and

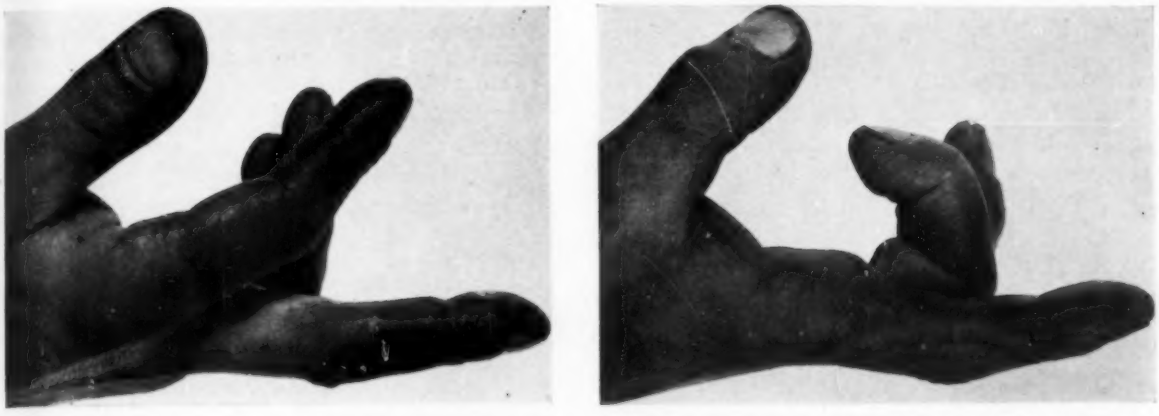

FIG. 33.—Male, aged 36 years. Perfect result from a repair of a profundus tendon in the middle finger, cut within ½ in. of its attachment and re-attached by an indwelling wire suture.

pulled down on to its attachment, which should have been freshened, and obviates the need for a difficult attempt to suture within the sheath. It also helps movement of this joint from the start, although I am not sure that early mobilization is of any great benefit. I have made no attempt to get the whole of the wire out but cut the ends off at skin level, and in only one instance has the end of the wire had to be removed later, as a very minor procedure under local anæsthesia.

The results here seem to be quite variable : some patients regain a full range of movements (*Fig.* 33) and some get merely stiffness of the terminal phalanx, but even the latter say that the finger is better than when the terminal phalanx was flail. I have not yet been able to determine why results vary, but have an idea that it is something to do with the amount of damage that occurs to the anterior surface of the interphalangeal joint, leading to adhesions within the interphalangeal joint (*see Fig.* 38).

4. When both Tendons are divided at any Point within the Digital Sheath and when the Profundus alone is divided at any Point proximal to ½ in. from its Attachment.—There is no doubt that in this group of cases the only likelihood of good results comes from the insertion of a free tendon-graft and I believe that no good will come from this operation unless the minutest attention to detail is paid.

TECHNIQUE

Donor Site of Graft.—I believe I am right in saying that I follow the teaching of Pulvertaft (1948) in using now, in almost every case, a free graft of one of the toe extensor tendons and I do this for the reasons that Pulvertaft does, as follows :—

has one of the most powerful grips that I have ever felt (*Fig.* 36).

5. One can always get a sufficient length.

The palmaris longus is probably the graft most commonly used, but this is inconstant, too thick, and often too short to be always satisfactory. I have in several instances used the proximal part of sublimis as a free graft, with success, as has Eyre-Brooke (1948), but I still think there is nothing to beat the toe extensor tendon.

Exposure and Preparation of Graft.—The implantation of one of these tendons should proceed in a very definite sequence, and thereby the procedure will be rendered easier and be more likely to succeed. The first step must be to expose the whole length of the finger very fully by an incision which is placed in the midline of the lateral aspect of the finger ; by so doing the digital vessels and nerve will be preserved in front of the line of incision, and there will be no danger whatsoever of the scar stretching and becoming a little keloidal, as has occurred in several cases I have seen where the incision has been placed on the anterolateral corner. There need be no hesitation in incising the whole length of the finger.

The next step must be to define the flexor sheath and to ensure that as much of it shall be preserved as is possible. The damaged portion of the sheath will almost certainly need to be excised as it will be filled with scar tissue, and I feel that excision is the correct procedure rather than an attempt to dilate this portion with bougies. Then the distal end of profundus is extracted, usually by incising the sheath over its attachment, and detached from its insertion. A hole is made through the base of the terminal phalanx using an Archimedes drill and a dental burr. This necessitates a drill-hole

anteroposteriorly through the base of the terminal phalanx at the level of profundus attachment, and if the small toe extensor tendon is used there will be little difficulty in threading it through the hole. I think that this method gives a more direct pull in the centre of the bone than the method which I believe Pulvertaft uses by making a hole horizontally through the base of the terminal phalanx. It is necessary to emphasize here that the actual threading of the tendon through the terminal phalanx is the very last step of the whole operation of free grafting.

The hole in the terminal phalanx having been prepared, the next step should be to excise the distal end of sublimis if this has also been severed, as I believe that this free end may actually anchor the proximal interphalangeal joint.

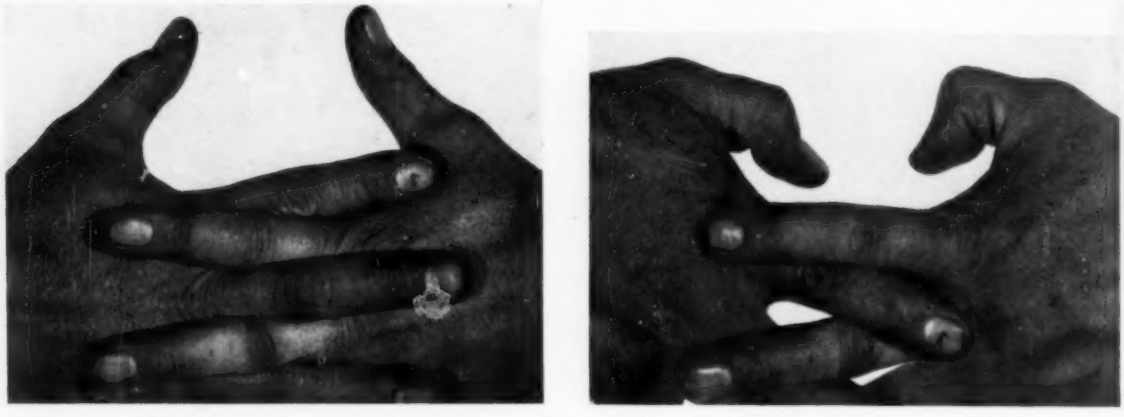

FIG. 34.—Male, aged 34 years. Division of flexor pollicis longus at the base of the proximal phalanx treated by end-to-end approximation using an indwelling stainless steel wire and immobilizing for three weeks.

Kinmonth (1947) has advised that even an intact sublimis should always be removed, because he says this leads to an easier introduction of the graft; this may be so in his cases because he used the comparatively thick palmaris longus, but there is absolutely no difficulty when a toe extensor tendon is used. There is therefore no point at all in removing an intact sublimis, especially as most people are agreed that the removal of the sublimis does in actual fact in some instances cause a slight loss of the complete flexion of that finger.

In reviewing my cases I noted that in several instances a good result had been marred by the inability of the finger to be fully extended and I had thought that this was due to interference with the capsule of the interphalangeal joint. It was suggested to me that this was due not to contraction within the capsule of the joint but to contraction of the flexible portions of the tendon-sheath tunnel, and since this suggestion was made some six months ago I have deliberately excised the soft flexible portions of the tendon-sheaths in the hope of eliminating this troublesome defect. In this connexion I was referred to the article by Rank and Wakefield (1952), wherein I note that they excise almost the whole of the tendon-sheath, leaving only small portions, but I note also that they have to deal with this complication of loss of full extension and illustrate a useful splint in the treatment of this condition. I would not agree that a radical excision of the tendon-sheath is a good thing to do. It is also interesting that some of the cases illustrated in Kyle and Eyre-Brook's (1954) article show this defect.

The next step is to locate the proximal end of profundus, to withdraw it into the finger wound, and to attach to it a length of thread, so that when eventually the profundus tendon is withdrawn through into the palm of the hand this thread will follow the normal metacarpophalangeal portion of the sheath and will serve as a means of placing the graft in the correct place.

The palm should then be incised and the proximal ends of sublimis and profundus located. The most convenient incision is in the main palmar crease and I emphasize, as all other writers have emphasized, that only transverse incisions should be made in the palm and, if the main incision, which can usually be sited in the crease, is insufficient, then another parallel incision should be made rather than any variety of longitudinal cut. It is usually quite easy to locate the severed tendon and to withdraw it into the wound.

It is essential at this point to determine the elasticity of the muscle belly, and if the profundus is inelastic, then the sublimis may be used; and if this also is inelastic then I do not hesitate to use the sublimis of an adjoining finger to act as the motivator for the graft. To use an inelastic muscle belly is to ensure a bad result.

A useful small procedure at this stage is to pull the profundus tendon as far out of the palm as it will come, and to prevent its further retraction by pushing through it, as Pulvertaft does, a needle which anchors itself on the edges of the incision. The sublimis tendon ends should be severed as high as possible in order to prevent them becoming adherent to other structures.

The Removal of the Tendon Graft.—A foot should always be prepared as a routine measure when any tendon operation is being undertaken. The tendon which is usually used is that of the fourth toe, and the incision is made along the whole length of the foot immediately over the tendon. This used to seem to me to be an extensive incision to make and in the early days I did try to remove this extensor tendon from two small incisions and using a tendon stripper, but found that this so

damaged the tendon as to make a successful outcome much less likely, so that now I make a cut perhaps 6 in. in length and remove the tendon from the base of the proximal phalanx to just inside the lower part of the cruciate ligament.

One or two points to keep in mind: Immediately under the incision is a main branch of the sural nerve which is quite easily visible and should be protected. Every endeavour should be made to remove as much paratenon as possible with the tendon and to remove what seems to be more than a sufficient length, it being for this reason that the lower part of the cruciate ligament is incised. The wound is then sutured and as a post-operative measure a Cellanband bandage is always applied to the leg to prevent any swelling and thereby lessen the risk of minor sepsis in the wound. I have never seen any functional interference with the foot or toes even when two tendons have been removed.

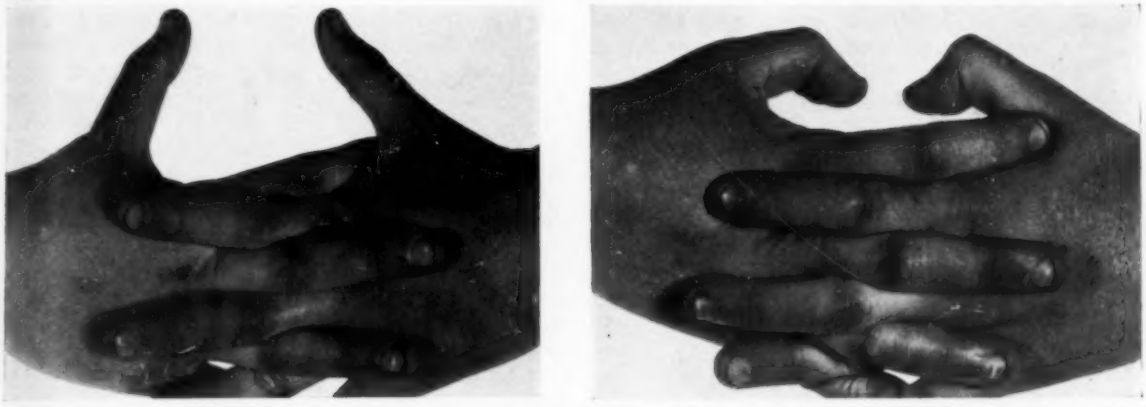

FIG. 35.—Male, aged 9 years. Cut right flexor pollicis longus treated by insertion of free graft from toe extensor tendon attached through hole in base of terminal phalanx; proximal attachment was above the wrist. It was in this instance possible to repair the pulley opposite the metacarpophalangeal joint using the original tendon-sheath tunnel. This was an early case and I believe nowadays that there is no necessity to take the graft above the wrist, as it works perfectly well when it lies within the mass of the thenar eminence. Note the slight loss of full extension.

Method of Attachment of Graft to Proximal End of Profundus.—I now use a V cut in the profundus just distal to the lumbrical attachment and, placing the one end of the free graft into the V, anchor it with interrupted braided stainless-steel sutures. Originally Pulvertaft's method of insertion was used, but I find the V to be easier and to give a smoother junction. It is, however, essential to use interrupted stainless-steel sutures because a continuous single-strand stainless-steel suture which gives an even neater junction has, in one or two instances, broken, and the graft has needed re-attachment. Since using the interrupted braided wire this difficulty has not been experienced. I doubt if the actual method of attachment matters a great deal here, except that I am assured by my colleagues that any method where the tendon ends are obliquely attached is mechanically stronger than a direct end-to-end approximation. Then the free end of the graft is attached to the thread which has been pulled through the tendon-sheath tunnel from the finger, and this is the clue to getting the graft in the correct place and thereby utilizing a very important and usually intact tendon-sheath pulley opposite the metacarpophalangeal joint. The tendon

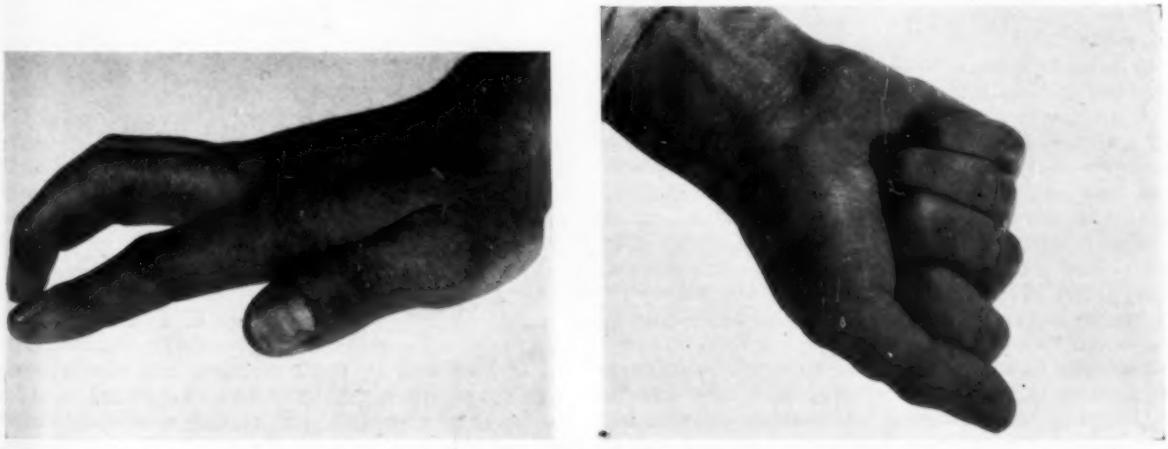

FIG. 36.—Male, aged 30 years. Cut profundii right third and fourth fingers treated by insertion of free tendon-grafts from the toes. These photographs illustrate a quite common trouble in the loss of full extension. Fortunately this did not bother the man and he had returned to a rather heavy job as a tool setter and was carrying this out perfectly well. The grip is extremely powerful. He is extremely pleased about the result.

can be quite easily threaded through the remaining tendon-sheath tunnels in the finger by the use of the same thread and through the hole in the base of the terminal phalanx.

At this point it is essential to contemplate whether the portions of the tendon-sheath which are already present are sufficient to prevent bowstringing of the tendon, and in some fingers where there has been a lot of damage it is necessary to form a new pulley

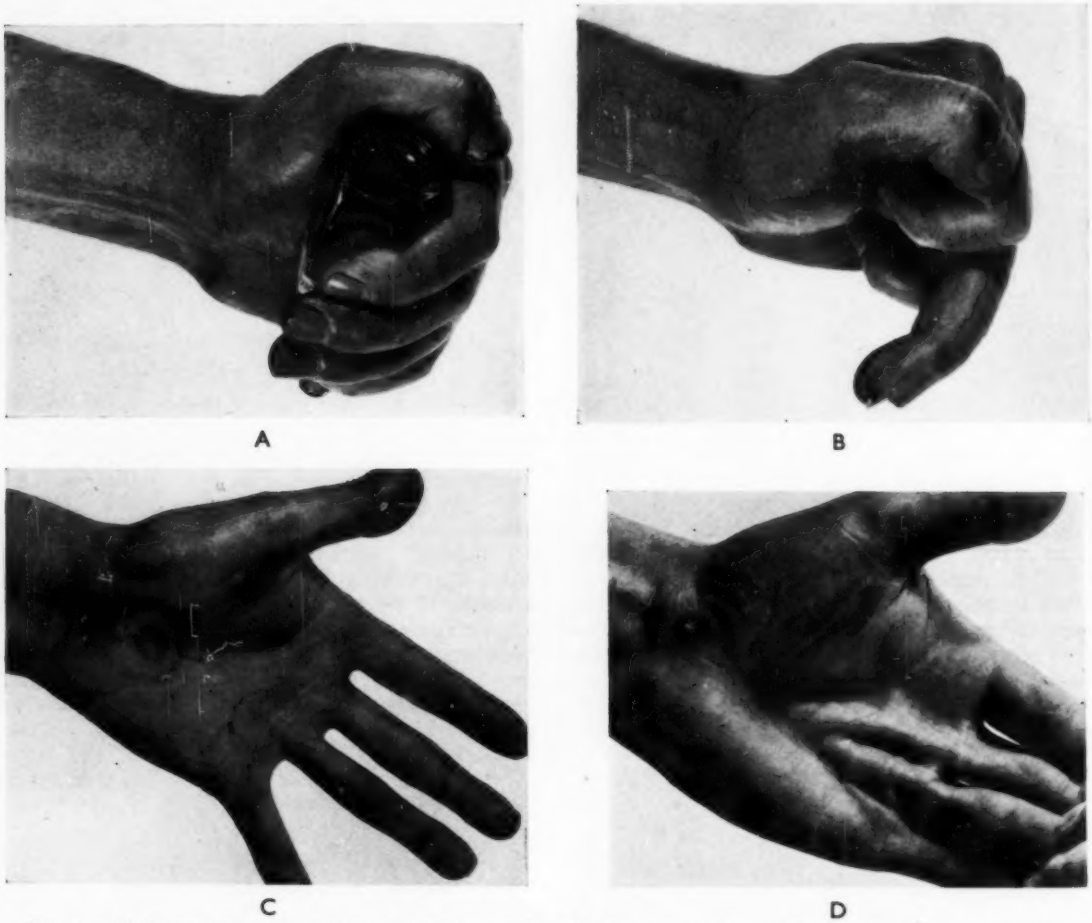

FIG. 37.—Male, aged 37 years. Division of sublimis and profundus opposite the proximal phalanges, treated by using the sublimis as a free graft. A, Indicates the powerful grip that he has when holding, in this instance, a bottle, but which he assures me is the grip he has when he is doing his fairly heavy machine job. B, Unfortunately represents his attempt to make an ordinary closed fist. D, Illustrates very definitely the reason, in that the tendons have been placed outside the very important metacarpophalangeal tunnel and are bowstringing across the joint. This case in particular indicates the importance of the pulley at this site. C, Shows the palm of the hand and the very little interference caused in this hand by the incisions which follow the crease or go across the palm.

because any tendon which bowstrings loses a great deal of its efficiency (*Fig.* 37) and may render the finger painful as well as useless. Sometimes there has been such gross destruction of the tendon-sheath pulleys that there is only one way of re-forming them, and that is by using a length of another toe extensor tendon, usually the fifth, and threading this around the phalanx between the bone and the extensor tendon and around the free graft, tightening it sufficiently to keep the tendon in reasonable apposition to the anterior surface of the phalanx. This is a procedure of which I have practical experience in three cases which are not included in this review. I find it a simple and mechanically satisfying procedure, and because I have seen, both in my own and other people's cases, fingers marred by a bowstringing tendon, I feel it is essential to carry it out. One of these cases has been recently reviewed and the picture is very encouraging; active flexion is present and there is no evidence of bowstringing. A similar procedure is described in Bunnell's *Surgery of the Hand.*

Length of Tendon.—In a number of my early cases I found it difficult to obtain the correct length of tendon and in most of them found the tendon was being left a trifle too long, so that I now tend to make the tendon deliberately a trifle too short. There is a simple way of estimating approximately the correct length. The hand is released from its holding splint completely, all forceps are removed and the fingers and thumb allowed to attain their nature posture; and it will be recalled that natural flexion is greatest in the little finger and progressively less up to the index. It is then perfectly easy, having threaded the graft through the hole in the terminal phalanx, to adjust it to the correct length, and that is why I mentioned in an earlier paragraph that although the hole in the terminal phalanx be made at that early stage, the tendon should not then

be threaded through it. Again, it is important to have corrected any bowstringing before one attempts to get the correct length.

To Immobilize or not to Immobilize.—This is indeed to my mind *the* question. In most of my early cases Pulvertaft's teaching was followed in attempting to get as firm a union as possible at both ends of the tendon-graft so that movements could be started within about forty-eight hours. Neither I nor my physiotherapist helpers have been very impressed by the progress that such cases make in the first few weeks, and the remarks of Kyle and Eyre-Brook (1954) on this point are also interesting. A few months ago I was considerably disheartened by finding that some of the V insertions had pulled out, but then my feelings were a little elevated when, after these damaged junctions had been re-attached and immobilized for some three weeks, they seemed to do remarkably well, and it was then that my views on early mobility changed, so that I now automatically immobilize every tendon repair in a plaster-of-Paris splint in a neutral position for three weeks, and feel quite definitely that, at the end of that time, they are more advanced than they would be if free movements were permitted from the start. Most people will agree that repair proceeds more rapidly and with less fibrosis if the damaged tissues are put at rest; we immobilize without hesitation end-to-end sutures, e.g., in the palm; why, therefore, should we not also rest these perhaps rather more tricky tendon-grafts? The experimental work of Mason and Allen (1941) is in support of rest. For the last six months my tendons have been immobilized and I feel that there is less reaction in the hand following this method, less pain, and that the eventual end-result is just as good, if not better, and is probably attained more quickly.

Tourniquet.—All the tendon repairs which I have done have been very considerably helped by the use of a tourniquet on the arm. This consists of winding up an Esmarch from the fingertips to the middle of the upper arm and then replacing it by the ordinary sphygmomanometer which the anæsthetist kindly maintains at 200 mm. Hg. I have not had the temerity to keep such a tourniquet on for more than about half an hour at a time, but find that it is a perfectly simple process to release it for a few minutes, perhaps while taking the graft from the foot, then to get it re-pumped up and to proceed again. It is certainly better to do this than to risk any nerve or muscle damage by prolonged application, as these operations may take anything up to an hour and a half.

Time of Operation.—This paragraph is deliberately inserted because it is the practice of some people to say that it is not very important when one does a tendon suture. I feel that it should be done as soon as is possible, as I have seen a muscle belly quite inelastic only six weeks from the date of operation. This is a pity because so very commonly these days it is possible to get on with the elective procedure during the third week, which I think is about the optimum time, and such an early procedure will eliminate the risk of fibrosis in the muscle belly. In the very young, again, I do not hesitate to repair tendons; I might hesitate, indeed, to do a tendon-graft, but I would make sure that the muscle and its tendon were joined, and thus prevent atrophy and fibrosis of the former, and then perhaps leave the child for two or three years until it had attained some size and then, if necessary, do a tendon-graft.

Physiotherapy.—Physiotherapy does play a part in the treatment of these cases when the plaster has been removed, in order to concentrate the attention of the patient on what he has got to do, and for this reason also I encourage the use of faradism, which my physiotherapists assure me is quite safe to use after the sixth week.

It is usually not necessary to keep patients on physiotherapy for longer than about three months,

FIG. 38.—This picture shows the wire which attaches the free graft to the terminal phalanx. It is, I think, of more interest in showing a fairly marked degree of periosteal reaction on the middle phalanx. It is possible to correlate this with some stiffness in the terminal interphalangeal joint occasionally. It does indicate that every care must be taken to preserve the anterior capsule and periosteum in these regions.

and they are all returned to work at the earliest moment, encouraged to use the finger, and it is explained to them that recovery is going to continue for twelve to eighteen months.

Contra-indications to Tendon Repair.—

1. *Sepsis.*—This heading is placed first because in these days, when penicillin is used liberally and often, it is not uncommon to come across wounds which have healed apparently by first intention, but which beneath the skin surface contain small pockets of pus which are well sealed off. In one case I had the misfortune to come across such a pocket of pus within the tendon-sheath in a hand which had had all eight tendons divided; I made the incorrect assumption that such pus must be sterile and went on to do direct sutures of the tendons. Shockingly gross sepsis followed, leading to sloughing out of all the tendons.

In another case, where a badly lacerated hand seemed to have healed by first intention, there was a small pocket of pus underneath the skin. The operation was immediately stopped, fortunately, because a slight flare-up of the infection in the wound occurred in the next few days. He was later grafted with a free tendon without any trouble.

2. Where a digital nerve has been damaged so that there is anæsthesia of large areas of the finger. I feel that a tendon-graft is of little value even if it succeeds, and is less likely to succeed than in a finger with normal sensation.

3. There is little point in attempting to make a finger flex if passive flexion is absent from the start. Some grossly damaged fingers have already suffered interphalangeal joint fibrosis and these as a rule are not good subjects for tendon-grafts or for any form of repair.

Complications.—I found that a few V insertions pulled apart, which was rather discouraging, and I feel that this was the fault in the early technique of using a single-strand stainless-steel suture. I mentioned previously that this gives a very beautiful V junction but I have noticed on many occasions how easily and rapidly this single strand fragments (*Fig.* 39); the problem has now been solved by the use of a braided stainless-steel wire suture which can be quite easily threaded on to Pulvertaft's

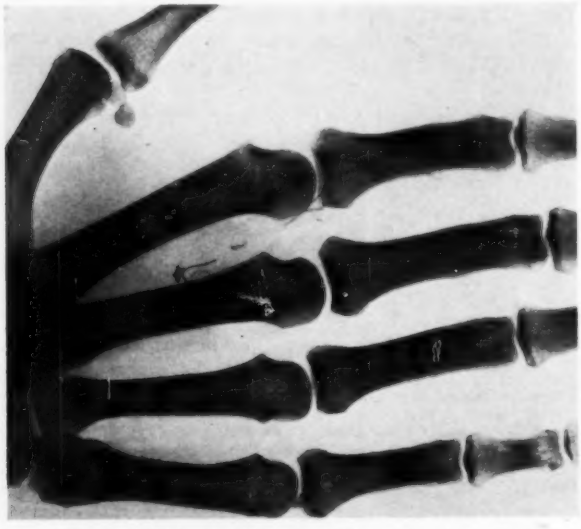

FIG. 39.—This is indicative of the help that a radiograph can give and shows very clearly the way in which stainless-steel wire fragments and pulls apart.

atraumatic needles and which is indeed very much more easy to use and, as far as I can ascertain at the moment, much less likely to fragment. It does also seem to be much stronger than the corresponding diameter of single-strand wire.

I think I have in 6 cases, some of which are in this series, had tendons pull apart, and I would like to emphasize that this is perfectly easy to detect clinically. It seems to me to occur usually within about the first three weeks, in those cases which are not immobilized, but I have never had any hesitation in re-opening these hands, re-attaching the tendons, using immobilization for three weeks, and then on the whole the results have been encouraging. During the last six months all my tendon repairs have been immobilized for three weeks, and in that time no V insertion has pulled apart.

I have notes of two cases in which the detachment of the graft from the terminal phalanx has been the cause of failure. The type of attachment has been different in each case; in one it was the method described, i.e., threading the free graft through a hole in the terminal phalanx; this case was not immobilized. In the other case the graft had been threaded but not sutured back on itself, but because it was too short it was taken straight through on to the skin of the dorsum of the finger and there anchored simply by a stitch to the skin. This finger was immobilized in a plaster for three weeks and yet despite immobilization it was found shortly after the plaster was removed that the tendon had pulled through the hole in the terminal phalanx; in other words, ordinary muscle tone had presumably been sufficient to start the detachment of this rather insecurely fixed free graft.

Both cases showed a most marked degree of fibrosis and integration of the distal two-thirds to three-quarters of the graft into the surrounding tissues, so that no definite structures were discernible at the end of the finger and the whole area had to be dissected out. I think these two cases merely illustrate the importance of a secure fixation of the terminal end of the graft, whether immobilized or not.

Primary Tendon Suture.—During the last four years I have found it possible to carry out primary tendon suture in cases which would normally have been dealt with by simple suture of the skin and a delayed tendon-graft. These I have done deliberately in order to be absolutely certain that with modern techniques and material bad results are still being obtained. Unfortunately this is only too true, and I would go further to say that not only is the result bad, but primary tendon suture makes the insertion of a free graft more difficult as a secondary procedure. This was particularly emphasized in the last case, where I found it necessary to dissect out a solid mass of fibrous tissue which consisted of tendon ends, suture material, and tendon-sheath over the proximal phalanx and extending on to the metacarpophalangeal tunnel, and I had to make a new pulley to prevent bowstringing. I feel quite definitely, therefore, that not only does primary tendon suture do no good in cases where one would normally use a free graft, but it may do actual harm. Some writers (May, 1947) are still advocating suture within the sheaths.

SUMMARY

I have attempted to convey in this article my firm belief that flexor tendon suture in the hand and fingers is very definitely worth while, and the fact that I continue to do tendon repairs after reviewing my own cases very critically is perhaps the strongest support of this belief. Meticulous attention to detail is necessary and I suggest that immobilization gives better results than mobilization; that a toe extensor tendon is the best variety of free graft; that a primary suture within the 'no-man's-land' of the tendon-sheath may not only do no good but may do actual harm; that one should not hesitate to re-operate on the occasional complications that occur; and that the final results should not be assessed for at least twelve months, when it will be found that the results are very much more encouraging.

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CHRONIC 'SIALECTATIC' PAROTITIS IN THE LIGHT OF PATHOLOGICAL STUDIES ON PAROTIDECTOMY MATERIAL

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CHRONIC parotitis presenting with intermittent swelling of one or both parotid glands is common and well recognized. Women appear to be affected more frequently than men (Payne, 1933). Not uncommonly it may start in childhood (Pearson, 1935; Jones, 1953). While occasionally there may be an obvious cause, such as obstruction by a calculus, the aetiology is usually obscure and has been the subject of much speculation. Infection (Payne, 1933), obstruction with secondary infection (Pearson, 1935), and congenital sialectasis (Bailey, 1945), have all been suggested. The course is uncertain. At times the attacks may be mild and cease spontaneously; at other times, in spite of the utmost ingenuity in treatment, they may recur so frequently and severely as to constitute a serious disability. This type of chronic parotitis may be classified as inflammatory-obstructive.

But there is also another type much less common and less well recognized. A swelling develops in one parotid gland, or occasionally both glands, which gradually increases in size. Clinically, differentiation from tumour may be impossible, and even histologically a mistaken diagnosis of tumour is not infrequently made on biopsy.

Seen occasionally and in isolation, these cases are often dismissed as belonging to the rare and obscure; or they may find refuge under the designation of 'Mikulicz disease', which under the guise of a diagnosis is usually merely the means of avoiding a diagnosis. Godwin (1952), under the heading of 'Benign Lympho-epithelial Lesion of the Parotid Gland', has recently collected and analysed 11 cases of this tumour-simulating lesion which he concludes is probably a chronic inflammation. But Foote and Frazell (1953) still incline towards a neoplastic explanation.

Within recent years a new weapon for the study of parotid disease has been provided in the operation of conservative parotidectomy, i.e., partial or total removal of the parotid gland with conservation of the facial nerve. The history of the development of this operation and its technique have been reviewed elsewhere (Patey, 1954). Parotidectomy was developed largely as a result of dissatisfaction with the results of the treatment of mixed parotid tumour by enucleation. But it was early recognized (Bailey, 1945) that the operation could have an important place in severe and intractable cases of chronic parotitis. It frequently happens in surgery that a weapon purely therapeutic in origin provides also the means for a better understanding of disease processes. Parotidectomy may thus be regarded not merely as an improved form of treatment for certain types of parotid disease, but also as providing material for pathological study much superior to that provided by the older operations of enucleation and limited biopsies. Some interim conclusions on serial section studies of parotidectomy material from cases of mixed tumour have been given elsewhere (Patey and Thackray, 1954, a). Similar studies on parotidectomy material from cases of chronic parotitis do not appear to have been carried out. Payne's statement of 1933 still appears true that "as regards the histology of the condition, very little in the way of accurate observation has ever been carried out".

In this paper we are reporting 9 cases of chronic 'sialectatic' parotitis, 8 of which were treated by total, subtotal, or extensive partial conservative parotidectomy. The pathological material so obtained was submitted to careful histological study, in many cases including serial sections. These studies seem to indicate that we are in fact dealing with different degrees and manifestations of the same fundamental pathological lesion, that the lesion is chronic inflammatory, and justifiably therefore termed 'chronic parotitis'.

CASE REPORTS

Case 1.—Male, aged 11½ years. H.72680, Aug. 3, 1954.

HISTORY.—History of intermittent swelling of both parotid regions for five years. The swellings come up two or three times a month and last two to three days. When swollen the area is red and tender. Left side worse than right. The condition is worse in the winter months. He has lost a lot of schooling and as a result is falling behind his companions in class.

ON EXAMINATION.—No swelling present on admission.

Sialography.—Bilateral sialectasis.

OPERATION (Aug. 23).—Left superficial parotidectomy.

POST-OPERATIVE COURSE.—Slight temporary facial weakness rapidly recovering.

PATHOLOGY.—Parotid tissue 1½ × 1½ × ¾ in. Macroscopically normal.

Microscopical examination showed stretches of the larger ducts to be surrounded by lymphoid tissue, with marked proliferation of the epithelial lining in the affected segments. There was widespread early atrophy of the acinar cells, but the normal lobular arrangement was still apparent. There were collections of inflammatory cells including polymorphs in some of the smaller intralobular ducts. Adjacent to many of the more severely affected ducts there were spaces surrounded by histiocytes and giant cells representing extravasated neohydriol.

Case 2.—Female, aged 13 years. H.42728, February, 1953.

HISTORY.—At the age of 5 years, following attack of mumps with both sides of the face swelling up, attacks of intermittent swelling of the right parotid gland. Schooling was interfered with and mothers in the neighbourhood would not let their children play with her. Became psychologically upset and was classified as a backward child. Treated by chemotherapy, physiotherapy, and radiotherapy, but without benefit. Shortly before patient's admission to hospital, she became so upset from the frequent pain and swelling and particularly

from the other children, including her own brothers and sisters, regarding her as a pariah that she tried to commit suicide by taking aspirin.

ON EXAMINATION.—Generally she seemed a healthy well-developed girl. Mentally, too, seemed normal and healthy except that occasionally she was a little sullen and irresponsive, and occasionally a little cheeky and pert. Apart from during attacks, nothing abnormal to be seen in the parotid. During attacks, the right parotid was diffusely and grossly swollen and tender. Nothing abnormal noted at the parotid duct orifice.

Sialography.—Mild diffuse glandular sialectasis right side.

AT OPERATION.—Right total conservative parotidectomy.

POST-OPERATIVE COURSE.—Temporary facial weakness rapidly recovering. Easter, 1954, left school and started work. Last seen April 13, 1954—everything satisfactory.

PATHOLOGY.—Two portions of parotid tissue, the larger superficial piece $2\frac{1}{2} \times 1\frac{1}{2}$ in., the smaller deep portion about 1 in. in diameter. Macroscopically normal.

Microscopically, scattered throughout the gland there were segments of medium-sized ducts showing proliferation of the epithelial cells narrowing the lumen, with heavy lymphocytic infiltration around the affected regions. The acini appeared normal. There were also other stretches of the major ducts with numerous mucous goblet cells lining them.

Case 3.—Male, aged 30 years. H.14027, June 23, 1951.

HISTORY.—In 1947 started getting swelling of both parotid glands. Subsequently, left side gave comparatively little trouble, but right side continued to swell intermittently. In typical attack gland swelled to size of Jaffa orange and very painful. Off work in attack up to three weeks. Attended several hospitals, had radiographs to exclude calculi, and several courses of different chemotherapeutic and antibiotic agents both generally and by instillation without permanent benefit. Referred to Middlesex with a view to radiotherapy but this thought inadvisable owing to marked inflammatory element now present. Transferred therefore to surgical department.

FIRST ADMISSION (June 23, 1951).—Mr. R. S. Monro noted increased viscidity of the saliva from right parotid orifice, which he regarded as the main cause of the obstruction and subsequent infection.

Sialogram.—Left side, remains of lipiodol from sialography four years previously. Generalized glandular sialectasis.

Right side, generalized glandular sialectasis with pooling of lipiodol.

Saliva.—Right side, pus cells +, 15 per cent eosinophils.

Culture.—Profuse *B. coli* and *Str. viridans*—penicillin insensitive.

Slitting up of both parotid duct orifices followed by regular dilatation. Condition of parotid improved. Discharged on dilatations, which he carried out himself.

SECOND ADMISSION (Aug. 3, 1952).—Trouble, particularly in right gland, had continued and he was re-admitted with large right parotid abscess. Incised and drained. Diathermy. Avulsion right auriculo-temporal nerve—Mr. R. S. Monro.

THIRD ADMISSION (Nov. 29, 1952).—Condition unchanged. (Stated that three years out of the last six he had been away from work because of parotid trouble.) Treated by total conservative parotidectomy right side. Immediate complete facial palsy, with failure of response to faradism. Recovery started after three months and by six months was substantially complete.

SUBSEQUENT COURSE.—Very well. No further trouble. Last seen April, 1954.

PATHOLOGY.—Two pieces of parotid tissue, the superficial portion $2\frac{3}{4} \times 1\frac{3}{4}$ in., the deep part $2\frac{1}{4} \times 1\frac{1}{4}$ in. Both pieces firm and fibrous and with coarse lobulation apparent when cut across.

Microscopical examination showed dense fibrous bands surrounding lobules composed of masses of lymphocytes and solid epithelial groups representing the major ducts. A suggestion of acinar arrangement at the periphery of the gland. Occasional nearly normal main ducts in the dense interlobular fibrous tissue.

Case 4.—Female, aged 50. H.59095, Oct. 27, 1953.

HISTORY.—Painless swelling left side of face for four months. No alteration with food. Biopsy elsewhere—diagnosis carcinoma ? secondary deposit.

ON EXAMINATION.—Hard swelling left parotid.

Sialography.—Marked glandular sialectasis with associated extravasation of dye into masseter muscle and tissues of cheek. Radiographs of face after total parotidectomy showed these extravasations still present. Radiography of removed parotid gland showed dye still present.

AT OPERATION (Nov. 2, 1953).—Total conservative parotidectomy.

POST-OPERATIVE COURSE.—Uneventful. Minimal facial weakness rapidly recovering.

PATHOLOGY.—Two portions of parotid gland, $2\frac{1}{2} \times 1\frac{1}{2} \times 1$ in. and $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{4}$ in. The specimen when cut across showed lobulation, as in the normal parotid, but the lobules were all much enlarged and white in colour, instead of the usual pale yellow.

Microscopically the lobules were composed of dense masses of lymphocytes in which were scattered islands of larger cells, some of which were lymphoid follicles and others solid masses of epithelial cells, representing solidified enlarged ducts. No normal acini to be seen, but almost normal ducts still present in the connective-tissue planes between the swollen lobules.

Case 5.—Female, aged 76 years. H.34208, June 3, 1952.

HISTORY.—One year progressively enlarging swelling right parotid region. Some pain. No variation with meals.

ON EXAMINATION.—Lump right parotid approximately 1 in.

Sialography.—Not done.

AT OPERATION.—Partial parotidectomy.

POST-OPERATIVE COURSE.—No facial palsy. Last seen Feb. 23, 1954. Well. No recurrence. Slight thickening of scar.

PATHOLOGY.—Nodule of tissue $1\frac{1}{2} \times 1 \times 1$ in. On section, apparently white tumour tissue, with translucent areas.

Microscopical examination showed here and there recognizable but atrophic and fibrotic parotid tissue, but the great part of the section was made up of dense masses of lymphocytes with scattered germinal centres surrounding much enlarged intralobular parotid ducts. Plasma cells present in the infiltrate immediately around the epithelial cell groups. The epithelial masses were formed partly of proliferated epithelial cells, sometimes becoming squamous, and partly from accumulation of mucus in the remaining lumen. The dilatation of the thickened ducts by mucus occasionally resulted in cyst formation.

Case 6.—Female, aged 68 years. Mr. Gardiner's case. Sept. 24, 1953.

HISTORY.—Swelling right parotid first noticed July, 1953. Slowly increasing in size, painless, and without symptoms.

ON EXAMINATION.—Apparent cystic swelling right parotid displacing lobule of ear upwards. Clinically thought probably mixed parotid tumour.

AT OPERATION (January, 1954).—Excision of soft mass right parotid with no apparent capsule.

POST-OPERATIVE COURSE.—Slight temporary facial palsy rapidly clearing up. Well, May, 1954.

PATHOLOGY.—Nodule of white tissue ¾ in. in diameter.

Microscopically the main mass was composed of lymphoid tissue with germinal centres and scattered epithelial islands, mostly solid, but with occasional lumen recognizable. At the periphery of the lump the lymphocytic infiltration decreased in density and atrophic but recognizable parotid glandular elements were seen.

Case 7.—Female, aged 60. Mr. Gardiner's case. June 25, 1951.

HISTORY.—Lump left parotid slowly growing for several weeks with slight pain.

ON EXAMINATION.—Small cystic mass left parotid gland. Clinically thought probably mixed tumour.

AT OPERATION.—Excision of ill-defined mass from left parotid.

Post-operative Course.—Uneventful. Well, October, 1953.

PATHOLOGY.—Portion of white tissue ¾ in. in diameter.

Microscopically parotid lobular arrangement still discernible, but acini all atrophied and intralobular ducts represented by solid cords of plump epithelial cells surrounded by delicate fibrous tissue and lymphocytes.

Case 8.—Female, aged 43 years. H.65791. March 16, 1954.

HISTORY.—Four years ago, painful lump in front of right ear. At first this varied in size usually in attacks lasting several days, with up to six weeks freedom. Since July, 1953, the lump has remained stationary.

ON EXAMINATION.—Semifluctuant swelling right parotid gland 1½ in. in diameter.

Sialography.—Multiple small opacities of small glandular calculi. Generalized glandular sialectasis with filling defect corresponding to lump felt clinically. Radiographs of gland after removal showed similar appearances.

AT OPERATION.—Superficial conservative parotidectomy.

POST-OPERATIVE COURSE.—Facial weakness recovering rapidly.

PATHOLOGY.—Superficial part of parotid 2 × 1½ × 1 in. When cut across, most of the gland looked nearly normal, apart from the presence of several pinhead calculi. Towards the back of the gland there was a rounded area 1 × ¾ in. where the lobulations, though still discernible, were swollen, blurred, and white in colour. This area was very soft and had a few small cysts in it.

Microscopically, the tumour-like area showed the picture of solid epithelial islands in a lymphoid tissue background. A few ducts in the area still showed a lumen and some were even cystic, but in this part there were no surviving acini. The rest of the gland was very patchy, quite normal regions alternating with areas where the acini were atrophic and the ducts swollen, almost blocked by epithelial proliferation, and surrounded by lymphocytes. Many spaces due to extravasated sialographic medium were seen, and calculi were encountered in considerable numbers.

Case 9.—Female, aged 67 years. H.4148, July, 1950.

HISTORY.—For many years (patient uncertain of dates, but states fifteen years or more) chronic non-painful, progressive enlargement of left parotid. Various treatments, including course of X-ray therapy, but without obvious benefit. For five years attacks of acute swelling right parotid, since when the left parotid too has been painful.

ON EXAMINATION.—Hard swelling 2 × 1½ in. left parotid at level of angle of jaw. Nothing abnormal in right parotid region on admission, but on a subsequent occasion swelling was seen.

Sialography.—Right side: Duct sialectasis with associated negative shadows in duct. *Left side*: Diffuse glandular sialectasis. Residual lipiodol in left gland on radiograph one year later.

AT OPERATION (July, 1950).—Biopsy left parotid gland.

SUBSEQUENT COURSE.—Continued to get intermittent swelling of the right parotid gland and persistent swelling of the left gland. Last seen in November, 1951.

PATHOLOGY.—Small portion of tissue ½ in. in diameter.

Microscopically insufficient material to make out the lobular pattern, but the larger ducts present in the specimen were lined by mucous goblet cells. The acini were still recognizable but appeared to be atrophying and there was considerable interstitial lymphocytic infiltration and some fibrosis.

CLINICAL FEATURES

Of the 9 cases of the series, the first 3 were typical examples of the inflammatory-obstructive type (*Cases* 1–3); 2 were treated by total parotidectomy and 1 by subtotal parotidectomy. Two of these were children, and the condition had caused so much loss of schooling over so many years that in spite of their being bright and intelligent fundamentally, they were educationally backward. In the girl, it had resulted in severe personality disturbances. The third case was an adult man (*Figs.* 40, 41), and during the six years he had suffered from the disease he had been for half this time attending hospitals and away from work.

Four cases (*Cases* 4–7) were all at first diagnosed clinically as neoplasms, 3 as mixed tumour and 1 as carcinoma. This last case was also at first regarded histologically as carcinoma, and was in fact referred to us after biopsy as a proven case of carcinoma. Of these 4 cases, 1 case was treated by total parotidectomy and the remaining 3 cases by extensive partial parotidectomies.

Cases 8 and 9 were interesting as being intermediate in type between the inflammatory-obstructive group and the tumour-simulating. In *Case* 8, the condition started with slight but typical inflammatory-obstructive features, but then continued as a typical tumour-simulating condition. As a result, she was referred to us with the diagnosis of mixed tumour. In *Case* 9 the condition was bilateral, on the one side being typically inflammatory-obstructive and on the other typically tumour-simulating. As will be seen later, the radiological and pathological features of all types of chronic parotitis are similar, in spite of the fact that the mode of clinical presentation may vary widely. The existence of these intermediate type cases is therefore important as giving unity to an apparently heterogeneous clinical picture.

RADIOLOGICAL FINDINGS

In most cases, straight radiographs of the parotid region and sialography were performed. In addition, in some cases treated by parotidectomy, radiographs were taken of the removed gland to determine the presence and distribution of residual lipiodol, and for comparison with the pathological findings.

Straight radiographs of the parotid usually showed nothing abnormal. It is well recognized that calculi are rare in the parotid, though we

occasionally found multiple microcalculi in the intermediate-sized ducts on pathological examination. Sometimes, too, these microcalculi showed up on radiological examination, particularly of the specimen after removal. The most characteristic radiological finding in chronic parotitis is so-called ' sialectasis ', and this has been recognized since the beginning of sialography. The main ducts are not

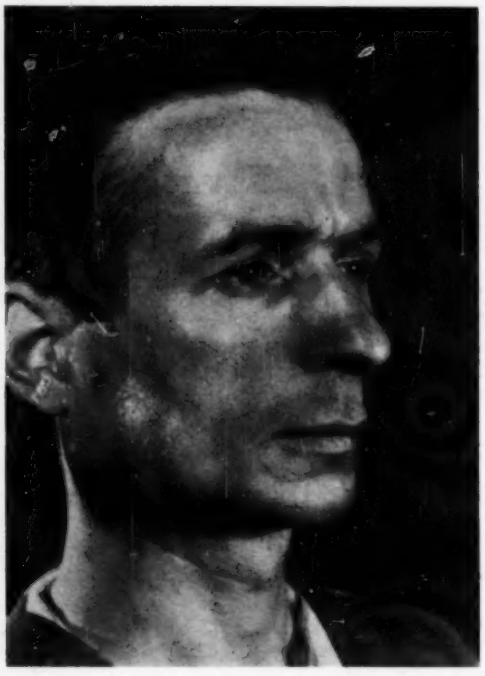

FIG. 40.—*Case* 3. To show swollen and inflamed right parotid gland before operation.

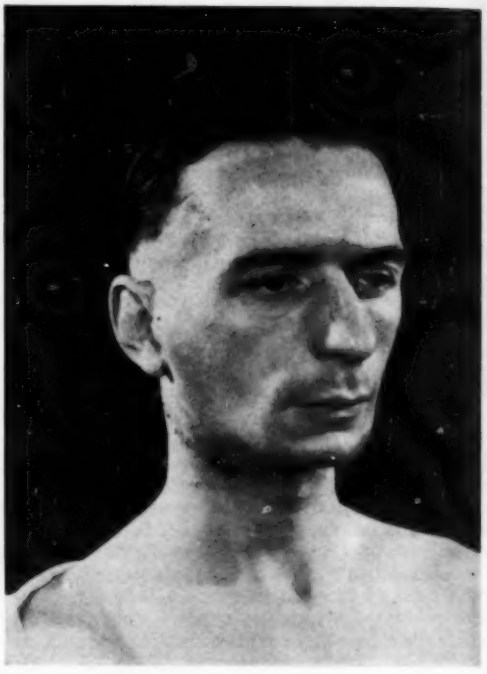

FIG. 41.—*Case* 3. Immediately after operation. There was temporary facial paralysis in this case which completely recovered in three to six months.

usually involved, and the typical picture is a glandular sialectasis, the ' dilatations ' being of the intermediate and smaller sized ducts (*Fig.* 42) (Payne, 1931). But from our pathological examinations we have found that this interpretation of the sialographic picture, which has come to be regarded as so obvious as to be almost axiomatic, is not correct. Though there is dilatation of the intralobular ducts, the main cause of the typical glandular ' sialectatic ' picture is extravasation of the lipiodol interstitially. The larger pools of lipiodol which are sometimes interpreted radiologically as indicating abscess formation, are often merely extreme examples of such extravasation. The evidence for these statements, and a description of the cellular changes produced in the gland by the extravasation, will be mentioned later with the pathological features and presented in detail elsewhere (Thackray, 1955).

If extravasation is the main cause of the ' sialectatic ' picture, then the other characteristic of sialography in chronic parotitis is not surprising, i.e., the tendency of lipiodol to remain in the gland. In several cases of this series residual lipiodol was demonstrated in the gland when the sialography had been carried out weeks, months, and sometimes (*Case* 3) even years previously.

These radiological findings are common to all types of chronic parotitis irrespective of the clinical picture. They may even be met with without clinical evidence of chronic parotitis, as we found in one case not included here in which total parotidectomy was performed for mixed tumour, and in which signs of chronic parotitis were radiological and pathological only. When the inflammatory process is advanced, the glandular substance may either be replaced by large aggregations of lymphoid tissue, or obliterated by hyperplastic and metaplastic changes in the epithelium of the ducts. In the former case the aggregated lymphoid tissue may constitute a local lump clinically, and a filling defect in a typical ' sialectatic ' picture radiologically (*Case* 8, *Fig.* 43). Or, if the ducts are obliterated by the hyperplastic changes, they will of course fail to fill.

PATHOLOGICAL FINDINGS

The pathological findings can be summarized as consisting essentially of progressive accumulation of lymphoid tissue around the intralobular ducts with associated epithelial hyperplasia and metaplasia. The secreting glandular elements atrophy and are replaced by lymphoid tissue. The findings are similar in character irrespective of the clinical picture. If a persistent lump is present in the parotid, either localized or diffuse, a particularly intense accumulation of lymphoid tissue will be found histologically in the area of the lump. The sequence of development of these changes will first be described, followed by a brief reference to the duct changes leading to the extravasation of lipiodol in sialography and the reaction of the tissues to this extravasation.

The gland in the earliest stages of the lesion is normal macroscopically. But microscopically there are scattered areas of heavy lymphocytic infiltration

around the larger intralobular ducts, usually with germinal centres appearing in the field of lymphocytes (*Fig.* 44). There may also be early thickening of the epithelial lining of the ducts. Occasional

FIG. 42.—Sialography of *Case* 1. The typical 'sialectatic' areas are well shown. As noted in the text, pathological investigations show that much of the sialectatic picture is due to extravasation outside the ducts.

ducts may be seen containing acute inflammatory cells, but there is no demonstrable blockage of the lumen and at this stage no changes in the secreting glandular tissue.

At a rather more advanced stage there may again be no macroscopical changes. But microscopically, in addition to the areas of lymphocytic accumulation around some of the larger intralobular ducts already described, there is more marked proliferation of the epithelial lining of the ducts which may in places be distinctly squamous (*Fig.* 45). As a result the lumen of some of the affected ducts may be occluded and the secreting acini of the corresponding lobule may atrophy, their place being taken by the progressive accumulation of lymphoid tissue. The main interlobular ducts show only minor changes, the brunt of the damage falling on the larger intralobular ducts. These changes are irregularly distributed throughout the gland, affected lobules alternating with normal ones.

In advanced stages of the lesion the gland is enlarged, and when cut across, though retaining its lobular arrangement, the enlarged lobules are oval or round on cross-section as contrasted with the rhomboidal outline of the normal lobules (*Fig.* 46). In colour they are whiter than normal parotid. Microscopically, at a low magnification the lobules seem to have lost all sign of the normal glandular arrangement of branching ducts and acini, and appear as though composed of uniform masses of lymphoid tissue. More careful inspection, however, reveals many scattered islands, which with a higher magnification are seen to be solid masses of epithelial cells infiltrated with lymphocytes (*Fig.* 47). The epithelial cells composing these islands are usually spheroidal but are sometimes squamous, whilst in some cases there may be a central cystic space. Although it seems natural to describe these groups of epithelial cells as 'islands' when looking at a single section, serial sections show that they are in fact cross-sections of greatly swollen solid ducts.

FIG. 43.—Radiograph of removed gland from *Case* 8. The lower part of the gland still contains much lipiodol from the pre-operative sialography. In the upper part, glandular elements have been almost entirely replaced by lymphoid tissue, giving a filling defect appearance (the dark band across this part is where a block has been removed for microscope).

FIG. 44.—Section of the gland from *Case* 1 at a very low magnification. The main duct below is normal, and there is a lobule of normal glandular tissue to the left. The lobule in the upper centre shows thickening and some dilatation of its intralobular duct with lymphoid tissue spreading peripherally to replace the glandular tissue of the lobule. The round germinal centres in the lymphoid tissue are well shown. (× 11·25.)

There is also great hypertrophy of the intraparotid lymph-nodes, which correspond to some of the lobular structures visible to the naked eye, and microscopically these show large lymphoid follicles with germinal centres in addition to proliferation of the epithelium of the ducts which are normally found in these nodes. Between the swollen lobules the fibrous connective tissue, sometimes with almost

normal looking major ducts running in it, may be comparatively unaffected.

Even in the early stages of the lesion, changes are present in the supporting connective tissue of the walls of the affected intralobular ducts. With appropriate stains, fragmentation with gradual disappearance both of the reticular and collagenous tissue supporting the duct wall may be demonstrated (*Fig.* 48). If sialography has been performed, clear spaces may be present near the weakened ducts (*Fig.* 49). By comparison of the topography of the microscopical sections with the radiographs of the macroscopical specimens, these clear spaces can be shown to correspond with the 'sialectatic' areas of lipiodol. If the sialography has been performed some weeks or more before the parotidectomy, these pools of oily material may be surrounded by typical macrophage and foreign-body giant-cell reaction. Eventually there is dense fibrosis, but in the absence of extravasation or actual abscess formation, fibrosis is not in general a striking feature (Thackray, 1955).

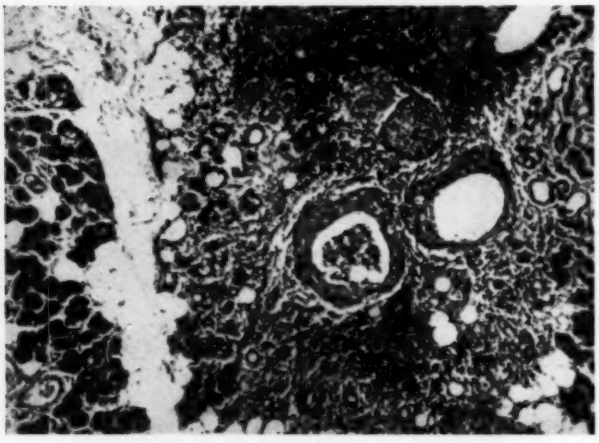

FIG. 45.—Part of a lobule from *Case* 8 showing squamous metaplasia in the intralobular duct. The branch above has lost its lumen, whilst there are pus cells in the lumen of one of the other divisions. Part of a normal lobule to the left of the field. (× 56·25.)

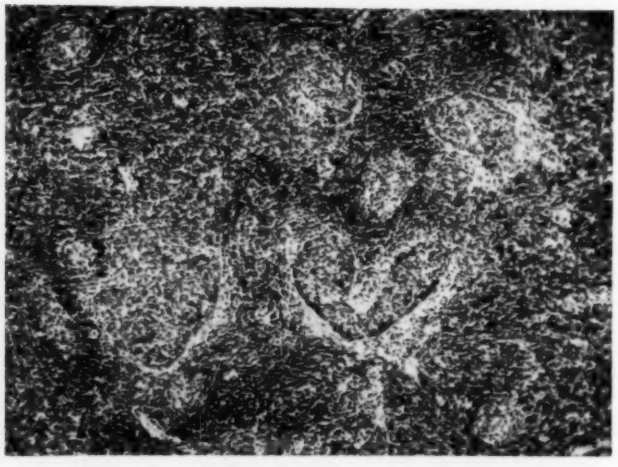

FIG. 47.—A typical low-power field from the parotid gland of *Case* 4. In a solid background of lymphocytes there are rounded germinal centres and what appear to be 'islands' of epithelial cells. This is the picture which may erroneously be called 'lympho-epithelioma' on a small biopsy. The islands are in fact sections of solidified ducts. (× 56·25.)

DISCUSSION

There is thus in the parotid a condition with two different clinical modes of presentation which may be described as inflammatory-obstructive and tumour-simulating. In both, the pathological picture is one of chronic inflammation differing in degree and distribution. In both the radiological picture is that of glandular sialectasis. This common pathological and radiological picture, combined with the existence of cases presenting clinically with features intermediate in type between the two extremes, indicates that we are dealing with different manifestations of the same condition rather than with fundamentally different conditions.

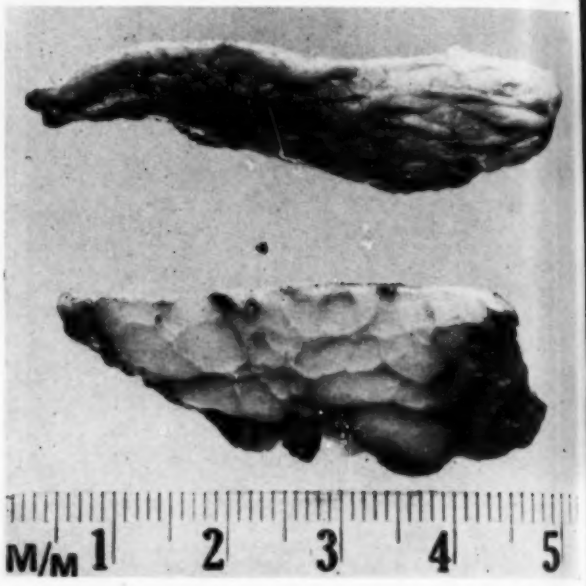

FIG. 46.—Cross-section of a normal parotid above compared with the gland from *Case* 4 below. The lobules are clearly visible in both specimens, but are larger, more rounded, and whiter in colour in the diseased gland, as contrasted with the more angular and distinctly yellowish colour of the lobules of the normal.

It is not possible at the present time to state the cause of these cases of chronic parotitis. Among many suggestions made are that it is a primary infection with secondary obstruction, or a primary obstruction with secondary infection. Bailey (1945) suggested that the primary condition was a congenital sialectasis. Allergy has frequently been suggested as a cause (Meyer, 1934; Monro, 1951; Smith, 1953). Though obvious infection is sometimes present with mucopus discharging from the parotid duct orifice, this is not constant, and it is possible that the infection is secondary. Though obstructive features, too, are often present, again it is usually impossible to say whether they are primary or secondary. The same applies to the microcalculi sometimes demonstrated pathologically. But whatever the cause, on the pathological and radiological evidence its main site of action would appear to be at the level of the intralobular ducts.

The fragmentation of the connective tissue supporting the intralobular ducts may have further

significance than the allowing of the extravasation of lipiodol interstitially during sialography. It is possible that the normal secretion of the gland, too, leaks through the weakened wall. Such leakage would provide a persistent or recurrent irritative factor. On this theory, the fragmentation of the duct wall would constitute the irreversible process resulting in persistence and progression of the inflammatory reaction, even though the original cause might have disappeared. Such a theory would well fit the clinical facts of the disease, but it must at present be regarded merely as theory, and the initial cause of the fragmentation is unknown.

Swelling of the parotid gland, intermittent or persistent, may of course occur as a result of obstruction of the main parotid duct as by a calculus, stricture, or œdema. In the few cases of this type that we have seen, however, if the obstruction is relieved as by the passage of the calculus, the condition clears up completely. In other words, there is no persistent irritative factor present other than the causative factor. Since parotidectomy is not indicated, we have had no opportunity of pathological studies on this type of lesion. But since there is no glandular 'sialectasis' on sialography, though there may be dilatation of the main duct,

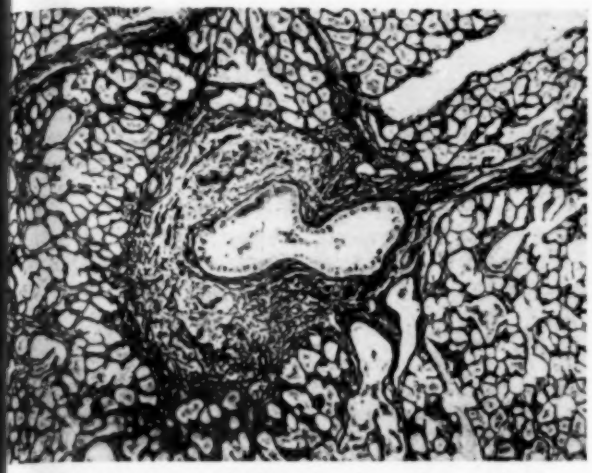

FIG. 48.—Silver-stained section from *Case* 1. At the periphery there is the black network supporting the unstained glandular acini. At the centre an intralobular duct is just about to divide; the branch to the right has its normal narrow supporting band of collagen and reticulin fibrils, that on the left is surrounded by a broad zone of unstained lymphocytes which have separated and fragmented the supporting tissue. In places, only the basement membrane separates the epithelium from the inflammatory zone. (× 56·25.)

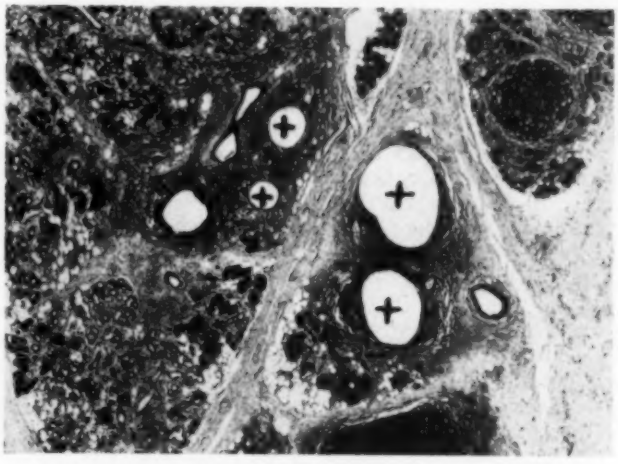

FIG. 49.—A section from *Case* 1 at a very low magnification. A normal main duct with its darkly staining epithelial lining is seen on the right; nearer the centre are two large extravasations into the lymphoid tissue following sialography; immediately beside the lower pool of contrast medium is the intralobular duct from which it escaped. In the lobule to the left there are two dilated ducts and two extravasations. (The extravasated areas are indicated by crosses.) (× 18·75.)

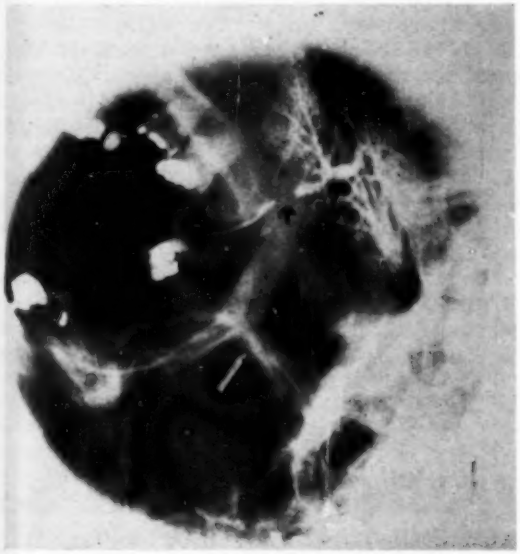

FIG. 50.—Sialogram to show negative shadow of non-radiopaque stone (indicated by arrow) blocking main parotid duct. There is dilatation of the duct system behind the obstruction but no extravasation, i.e., 'sialectasis'.

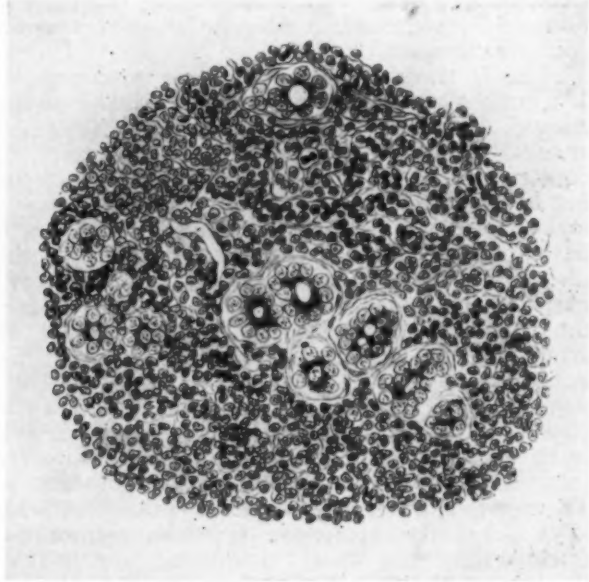

FIG. 51.—Photograph of microscopical drawing of lacrimal gland from Mikulicz's original paper, showing remains of epithelial elements and background of indeterminate round cells.

it would seem unlikely that the characteristic pathological lesion of chronic parotitis in the intralobular ducts as described above is present (*Fig.* 50).

The differentiation of chronic parotitis from other conditions of the parotid may present difficulties histologically as well as clinically. We have mentioned a case which was referred to us as a histologically proven case of carcinoma. Both carcinoma, especially lympho-epithelioma, and conditions primarily affecting lymph-glands (temporarily localized in the parotid), e.g., lymphosarcoma, reticulosis, leukæmia, have to be considered in the histological differential diagnosis. In a small biopsy specimen, the decision may be a difficult one, but when a large amount of tissue is provided, all degrees of the inflammatory process can usually be recognized and the diagnosis established. Tuberculous parotitis is rare, but the histological examination readily establishes the diagnosis (Patey and Thackray, 1954, b).

In the past it seems fairly certain that many cases of chronic parotitis have been labelled ' Mikulicz disease ' (*Fig.* 51). Godwin has recently recapitulated the main facts about ' Mikulicz disease ' and we do not propose to repeat them here. Mikulicz (1892) himself was unable to come to any firm conclusion about the nature of his case, but if it could be re-studied fully, it would probably now be classified under a recognized pathological heading. But since such re-study is not possible, the terms ' Mikulicz disease ' and ' Mikulicz syndrome ' are bound to lack precision; and unless they are abolished the danger will continue that an observer faced with an obscure salivary swelling will place it under this eponymous heading to avoid making an accurate diagnosis.

Finally there is the question of management. If a patient presents with a possible tumour of the parotid, then the diagnosis needs establishing by surgical exploration. The modern operation of conservative parotidectomy is an admirable means not only of providing adequate material for pathological diagnosis, but also, if the diagnosis proves to be chronic ' sialectatic ' parotitis, for removing the disease. If the patient presents with inflammatory-obstructive symptoms, the diagnosis is obvious, but the decision on treatment may be very difficult. If symptoms are severe and disabling, as in the inflammatory-obstructive cases of this series, conservative parotidectomy is clearly indicated and the results are most satisfactory. But in less severe cases in which parotidectomy is not justifiable, treatment is at present uncertain and unsatisfactory. There are, however, two negative points that arise from our findings. In the first place, since the essential lesion of chronic ' sialectatic ' parotitis is at the level of the intralobular ducts, no benefit is to be anticipated from procedures involving the main duct and duct orifice. This is not to say, however, that these procedures may not be valuable for lesions actually of the main duct and duct orifice. And secondly, since sialography in chronic parotitis is so frequently associated with extravasation of lipiodol, the possible advantages of sialography should be carefully weighed against the disadvantages. Sialography is useful in excluding chronic ' sialectatic ' parotitis by showing a normal duct system, and particularly in demonstrating obstructions in the main duct not showing on straight radiographs. But the price of these advantages has to be paid by the patients with chronic parotitis who have extravasated lipiodol in their glands. It would thus seem advisable to introduce much smaller quantities of lipiodol. And we would recommend as the standard amount to be injected ¼–½ c.c. instead of the usual 2–3 c.c., and to inject more than ½ c.c. only with the greatest caution and X-ray control.

SUMMARY

1. The modern operation of conservative parotidectomy, i.e., parotidectomy with conservation of the facial nerve, provides valuable material for the pathological study of chronic ' sialectatic ' parotitis. A study of 9 such cases is reported.

2. Chronic ' sialectatic ' parotitis presents clinically in two chief types—inflammatory-obstructive and tumour-simulating. Intermediate types also occur.

3. The characteristic radiological picture of chronic parotitis is one of glandular ' sialectasis ', but there is evidence that a large part of the ' sialectatic ' picture is due to extravasation of lipiodol interstitially.

4. The most striking changes histologically are progressive accumulation of lymphoid tissue around the intralobular ducts with associated hyperplasia and metaplasia of the epithelium of the ducts and atrophy of the secreting tissue.

5. Thinning and fragmentation of the connective-tissue walls of the intralobular ducts occur at an early stage, and it is through these weakened intralobular ducts that extravasation of lipiodol occurs during sialography.

6. In view of these findings, a critical reconsideration of the technique of sialography is indicated.

7. The cause of chronic ' sialectatic ' parotitis is unknown, and treatment is consequently often difficult and unsatisfactory.

8. But in the tumour-simulating group and in disabling degrees of the inflammatory-obstructive group, conservative parotidectomy may be of great value.

We have to thank Mr. R. H. Gardiner for the pathological material of *Cases* 6 and 7; also Dr. J. N. Pattinson for the radiological investigation.

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THE SURGICAL ANATOMY OF THE ANAL CANAL

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THE foundation of modern surgical teaching on the anatomy of the anal canal was undoubtedly laid by Milligan and Morgan in their now classical papers on the subject (Milligan, 1942; Milligan and Morgan, 1934, 1937; Morgan, 1936). Their lucid description was based on Peter Thompson's exhaustive monograph on the *Myology of the Pelvic Floor* (1899), and on original histological studies of the anal region in surgically removed rectums, combined with confirmatory observations at operations for hæmorrhoids, fissures, and fistulæ. The general conception of the anatomy eventually reached by them has been clearly depicted in their well-known diagram of a longitudinal section of the anal canal (*Fig.* 52).

According to them the external sphincter ani consists of three parts—the subcutaneous, the superficial, and the deep—instead of the two parts generally described in standard anatomical texts. From their investigations it would also appear that the longitudinal muscle-fibres of the rectal wall are prolonged downwards, forming an intermuscular septum between the external and the internal anal sphincters, and ending below the lower margin of the latter by dividing into two diverging fibromuscular septa: (1) An outer one which runs laterally between the subcutaneous and superficial parts of the external sphincter to become continuous with a layer of fascia separating the ischiorectal from the perianal space—*the septum of the ischiorectal fossa*; and (2) An inner one which runs medially between the internal and external sphincters to be attached to the skin lining of the anal canal below the mucocutaneous junction—*the anal intermuscular septum.*

Milligan and Morgan have directed particular attention to the subcutaneous part of the external anal sphincter which they maintain is clearly demonstrable on clinical examination and during operative dissection of the anus as a distinct ring of muscle without attachments—the so-called 'umbrella ring'. They claim for this structure a close aetiological relationship to fissure-in-ano. According to them the muscle which underlies a chronic anal fissure and is so often exposed in its floor is the subcutaneous external sphincter. They believe with Blaisdell (1937) that spasm of this part of the external sphincter is important in the genesis of fissure and that its division is an essential step in the radical surgical treatment of this condition.

However, recent work by Eisenhammer (1951, 1953) in South Africa has cast considerable doubt on the importance of the external sphincter in the aetiology of fissure-in-ano. He claims to have shown by numerous dissections that the muscle which forms the base of a dorsal anal fissure is invariably the lowermost part of the internal sphincter. He has been induced by these findings to treat patients with anal fissure by a simple division of this muscle—*internal sphincterotomy*—and maintains that this is usually followed by speedy cure. In this latter contention he has been strongly supported by our colleague, Mr. H. R. Thompson, who has kindly permitted us to state that in an extensive experience of internal sphincterotomy for fissure-in-ano he has had generally satisfactory results. It seemed to us, therefore, that the time was ripe for a critical review of certain aspects of the anatomy of the anal region, and in this paper we describe an anatomical investigation which we recently undertook at St. Mark's Hospital.

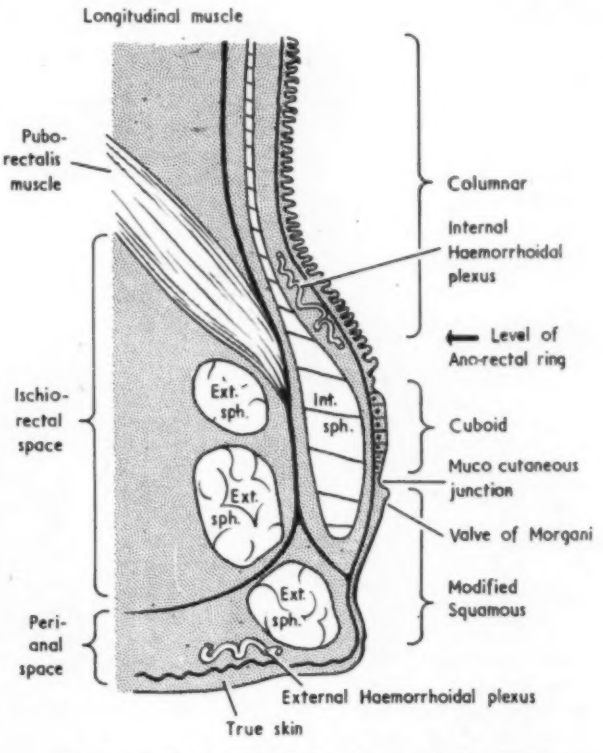

FIG. 52.—The Milligan-Morgan diagram of the anatomy of the anal canal; a composite drawing based on the writings of Milligan and Morgan.

MATERIAL AND METHODS

Our inquiry has proceeded along three lines:—

1. Histological Sections of the Anal Canal.—Fourteen operation specimens of the rectum, removed by abdominoperineal excision, provided the histological material. We realized that in these operation specimens some distortion of the anal canal was inevitable, especially at the lower end, owing to the severance of the natural moorings of the anus and rectum. After paraffin-fixation, sections were cut in the coronal and sagittal planes using the sledge microtome. The sections were stained by (*a*) hæmatoxylin and eosin, (*b*) van Gieson's technique, and (*c*) Weigert's method.

2. Digital Examination of the Living Anus.—In some 90 clinical cases, during ordinary routine rectal examination, the opportunity was taken to identify by palpation certain parts of the anal musculature, and to attempt to correlate the findings with the histological conclusions in Section 1 and the operative dissections in Section 3.

3. Extended Dissections during Operations on the Anal Canal and Rectum.—In 12 cases undergoing ligature and excision of internal hæmorrhoids and 10 cases having excision of an anal fissure, an extended dissection was carried out to identify the anal sphincters and other anatomical structures. This dissection was greatly facilitated by rendering the field practically bloodless by a preliminary perianal injection of 30 c.c. of a 2 per cent xylocaine solution containing 1–80,000 adrenaline hydrochloride.

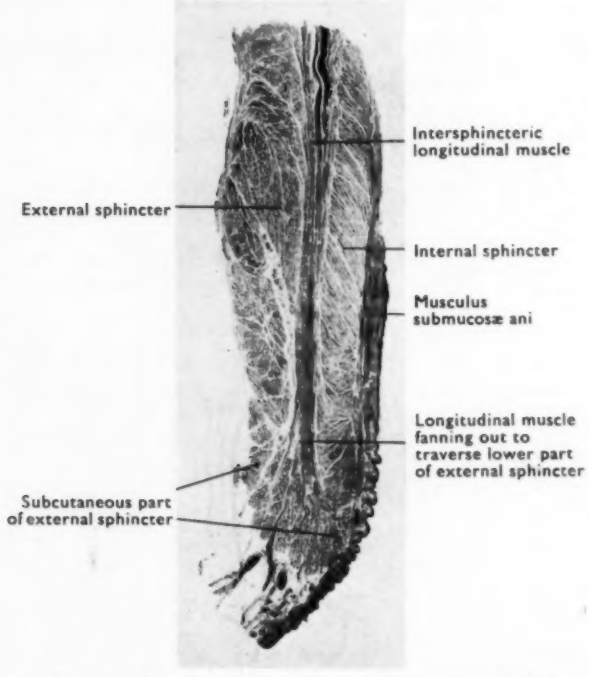
Intersphincteric longitudinal muscle
External sphincter
Internal sphincter
Musculus submucosæ ani
Longitudinal muscle fanning out to traverse lower part of external sphincter
Subcutaneous part of external sphincter

FIG. 53.—Adult anal canal. Longitudinal coronal section.

In addition, in 4 patients being treated by abdomino-perineal excision of the rectum for carcinoma, the perineal dissection was carried very close to the anal sphincters so as to permit of a close inspection of the outer aspect of the external sphincter muscle and the under aspect of the levatores ani where they meet the sphincter. The levator and sphincter musculature were further examined when the rectal specimen had been removed.

HISTOLOGICAL FEATURES

The Internal Anal Sphincter.—In longitudinal sections in both coronal and sagittal planes the most striking structure is the internal sphincter, which is much more substantial than it would appear in the Milligan-Morgan diagram (*Figs.* 53, 54). Superiorly it is continuous with the circular muscle coat of the rectum and inferiorly it ends with a well-defined rounded edge ¼ in. to ½ in. above the level of the anal orifice. A remarkable feature of the muscle is the manner in which its constituent muscle-fibres are disposed. These are grouped into discrete elliptical bundles which in the upper part of the sphincter lie obliquely with their transverse axes running internally and downwards, giving them an imbricated arrangement. This obliquity becomes progressively less as the internal sphincter is traced downwards, so that in the lower part of the muscle the bundles lie horizontally and some of the lower ones even incline slightly upwards. Sections stained by Weigert's method show that the internal sphincter consists of plain muscle-fibres.

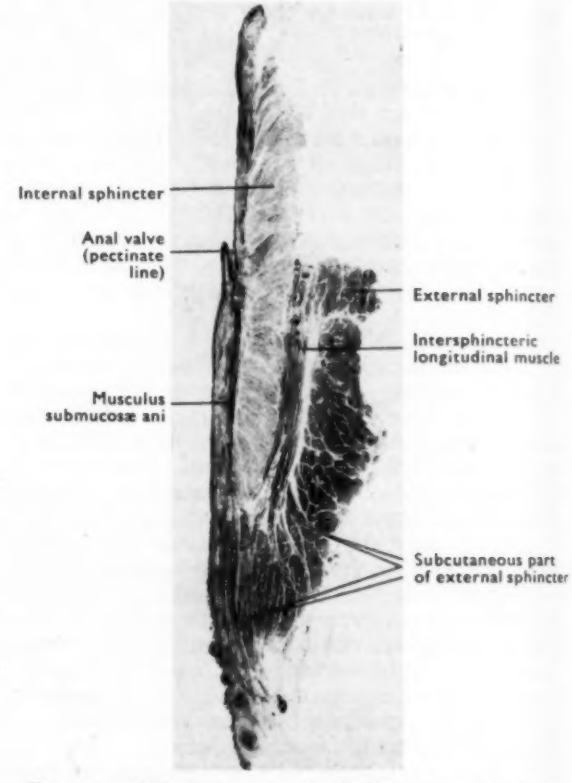

FIG. 54.—Adult anal canal. Longitudinal coronal section.

The Mucocutaneous Lining of the Anal Canal.—Particular care was taken to determine how much of the anal canal has a cutaneous or squamous epithelial covering and how much a mucous one. In some of our specimens the pectinate line (the so-called mucocutaneous junction, or line of the anal valves) was marked by an injection of indian ink, and its position relative to the sphincter musculature noted in the subsequent histological sections (*Figs.* 54, 55). Usually it was found to lie at a level between the middle and the junction of the middle and lower thirds of the internal sphincter, so that approximately the lower half or one third of this muscle has a cutaneous covering. This is in agreement with the findings of Ewing's (1954) recent careful study on the subject. Closer histological examination of the epithelial lining of the anal canal shows that *below the anal valves* the canal is lined with skin modified, as pointed out by Milligan and Morgan, by being devoid of hair

follicles and glands, and continuous below with the true skin of the perianal region. *At the anal valves themselves*, surprisingly, the epithelium undergoes no striking change except that it becomes thinner. It still consists of several layers of rather flattened cells, the more basal ones being cuboidal in shape (*Fig.* 55 B). *Above the anal valves* this type of lining continues almost up to the anorectal ring before giving place to the columnar epithelium of a typical intestinal mucosa (*Fig.* 55 A). Milligan and Morgan (1937) regard this epithelium, which lies between the valves and the commencement of columnar cells—and which is sometimes badly termed ' transitional ' epithelium—as being a modified form of intestinal mucosa, thus conforming to the embryological concept of the anal valves as marking the junction of the ectoderm and entoderm. We are not aware of any histological criteria that establish beyond doubt the precise origin of these cells, which in our view could equally well be modified squamous or cutaneous epithelium. We are therefore uncertain as to whether the ectodermal lining of the canal terminates at the valves or extends proximal to them to the upper part of the anal canal, and under the circumstances consider it wiser to avoid the use of the term ' mucocutaneous junction ' as synonymous with the pectinate line.

The External Anal Sphincter.—On coronal section (*Figs.* 53, 54) the external anal sphincter is seen to extend farther downwards than the internal sphincter and the lowermost portion curves medially to occupy a position below and slightly lateral to the lower rounded edge of the internal sphincter and close to the skin of the anal orifice. In none of our lateral radial sections could we find any clear suggestion of division of the external sphincter into three separate parts as described by Milligan and Morgan (1934). However, the lowermost or subcutaneous part of the muscle which lies below the internal sphincter does differ from the rest of the external sphincter in that it is traversed by longitudinal muscle-fibres which split it up into several distinct circular muscle bundles. At its uppermost end the external sphincter fuses with the puborectalis part of the levator ani muscle and it is quite impossible on histological section to say where one muscle ends and the other begins. Both muscles are, of course, made up of striped muscle-fibres.

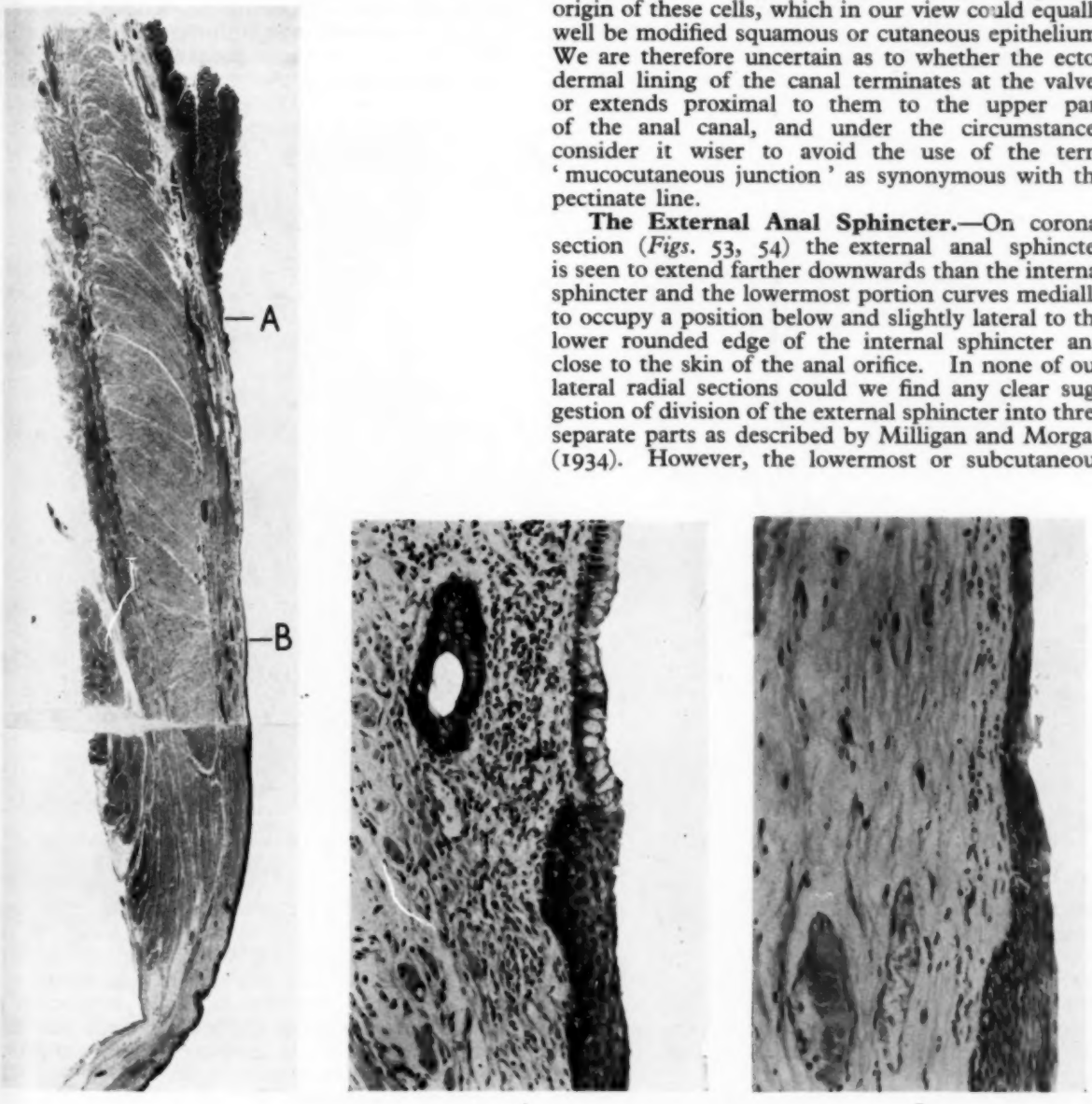

FIG. 55.—Adult anal canal. Longitudinal coronal section. A indicates lower limit of true intestinal or columnar epithelium as determined histologically (*see photomicrograph*). B indicates the level of the pectinate line as seen macroscopically; microscopical section at this point shows that the lining of the anal canal here is made up of several layers of cuboidal or slightly flattened epithelial cells.

The Longitudinal Muscle-fibres.—In coronal and sagittal sections (*see Figs.* 53–55) the main layer of longitudinal muscle-fibres in the anal canal is seen to lie between the internal and external sphincters. Histologically this layer consists of non-striped muscle-fibres mixed with elastic tissue. Traced upwards it is continuous with the outer longitudinal muscle-layer of the rectal wall and is joined by some striped fibres of the levator ani. Traced downwards it is seen to break up opposite the lower border of the internal sphincter into a number of septa which diverge fanwise and pass radially through the lowermost part of the external sphincter. Some of these diverging fibres are attached ultimately to the skin of the anal and perianal region from a point a little below the internal sphincter to well beyond the anal verge, while others lose themselves in the fat surrounding the anal canal (*see Figs.* 53, 54, 55). It will be appreciated that this mode of insertion of the lower end of the main longitudinal layer of the anal canal into skin and fat, which corresponds accurately with the arrangement described by Wilde (1949), differs notably from that figured by Milligan and Morgan (1934), particularly in that there is no strong circumferential attachment of longitudinal fibres to the skin in the region of the intersphincteric groove.

An additional layer of longitudinal fibres which was not mentioned by Milligan and Morgan (1934) but was first described by Fine and Lawes (1940), is one which lies on the inner aspect of the internal sphincter under the anal mucosa and skin. They have named it the musculus submucosæ ani. This layer was also clearly illustrated by Wilde (1949) and was a constant feature in all our sections, though it varied considerably in thickness in different specimens (*see Figs.* 53, 54). It is composed of unstriped muscle-fibres together with elastic connective tissue, and would appear to be derived chiefly from strands of the main intersphincteric longitudinal layer which make their way inwards and downwards between the bundles of the internal sphincter (*see Figs.* 55, 57). Inferiorly a few of the fibres of the musculus submucosæ ani become continuous around the lower edge of the internal sphincter with the innermost fibres of the main intersphincteric longitudinal layer. But the majority continue downwards and outwards superficial to the subcutaneous part of the external sphincter, to be attached to the skin of the anus and perianal region (*Fig.* 56). This extension constitutes the corrugator cutis ani of Ellis (1878) and Milligan (1942). Wilde (1949) has stated that this superficial radiating longitudinal layer contains no actual muscle tissue, but in our sections plain muscle could generally be recognized.

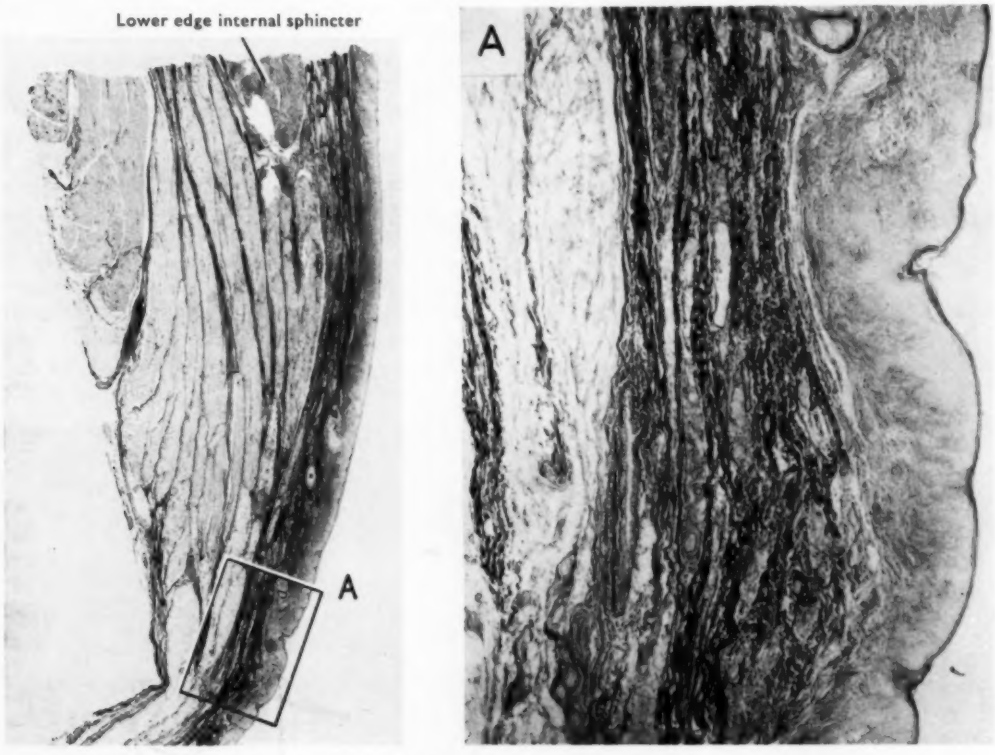

FIG. 56.—Adult anal canal. Weigert stain shows elastic fibres which are continuous with the longitudinal muscle-fibres. Inset A is magnified to show these elastic fibres inserting themselves into the dermis.

DIGITAL EXAMINATION OF THE INTACT LIVING ANUS

As Milligan and Morgan (1934) have pointed out, the lower edges of the internal and external anal sphincters are readily recognizable on digital examination of the anus. If the finger is inserted into the anal canal and then gradually withdrawn whilst gently pressing in a posterolateral direction, a distinct groove can be felt just inside the anal

orifice (*Fig.* 58). The upper rim of this groove is the rounded lower border of the internal sphincter, the lower rim the upper aspect of the subcutaneous free border of the external sphincter. On circumferential palpation the lower edge of the internal sphincter is found to form a circular ring of muscle, but the lowermost part of the external sphincter has usually a slightly oval shape, with the long axis running anteroposteriorly; sometimes, indeed, extensions can be felt running backwards from the posterior edge of the external sphincter towards the coccyx (*Fig.* 59). As a consequence of the differences in shape, the anterior and posterior parts of the external sphincter are somewhat farther

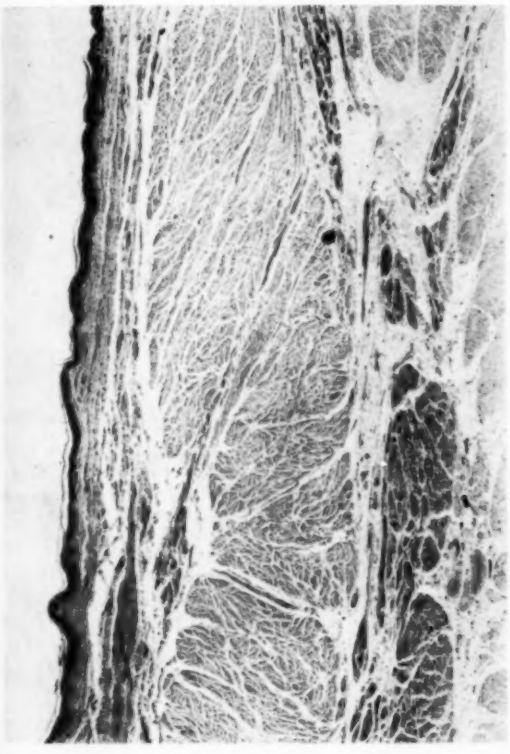

FIG. 57.—Adult anal canal. Longitudinal coronal section. High-power view to show fibres of internal sphincter becoming continuous with the musculus submucosæ ani.

away from the anal verge than the lateral portions and often less easily palpated. It is possible by firm pressure with the finger to displace the lateral portion of the external sphincter in an outward direction for half-an-inch or so. Conversely, when the patient is asked to contract the anus the lower edge of the external sphincter can be felt to undergo active contraction and to provide a tight closure of the anal orifice. If the lower edge of the internal sphincter is palpated during anal contraction it is found that this muscle also contracts, presumably owing to compression by the voluntarily contracting upper two-thirds of the external sphincter which surrounds it.

The anal intermuscular depression of Milligan and Morgan—perhaps better termed the 'anal intersphincteric groove'—corresponds to the lower end of the interval between the internal and external sphincters. It is remarkable, however, that this groove should be so wide—usually about ¼–½ in.—for it will be remembered that in the longitudinal sections of the anal canal the lower end of the external sphincter was closely applied to the inferior edge of

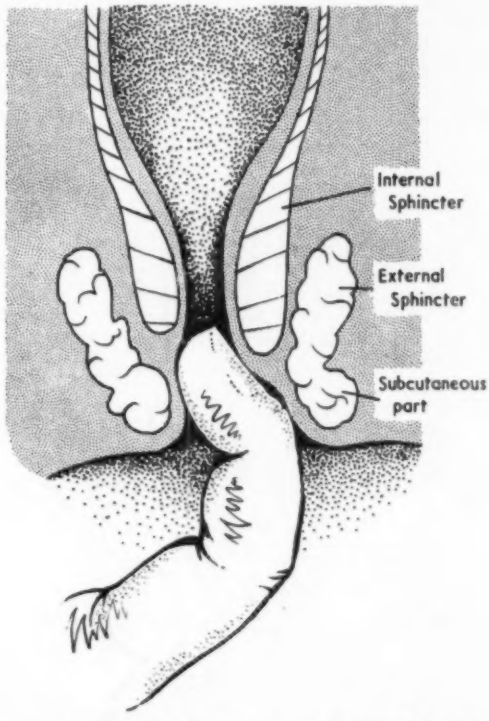

FIG. 58.—Digital palpation of the anal intersphincteric groove.

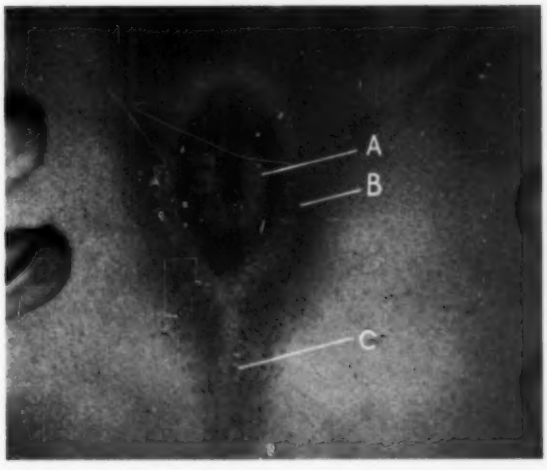

FIG. 59.—Photograph of the anal region in a patient with especially prominent anal sphincters. The lower margin of the internal sphincter shows as the inner circular ridge (A), the lower edge of the external sphincter as the outer elliptical ridge (B), with fibres of the latter extending backwards to the coccyx forming the midline posterior ridge (C).

the internal sphincter so that only a potential gap existed between them. It would appear, therefore, that in the living subject the lower part of the external sphincter lies farther downwards and outwards relative to the anal orifice than it does in fixed sections of the excised anal canal.

OPERATIVE DISSECTION OF THE ANAL REGION

During Hæmorrhoidectomy.—The technique followed in this operation was essentially that described by Milligan and Morgan (1937) (*Figs.* 60, 61). It will be recalled that in their operation artery forceps are applied to the skin and mucosa-covered parts of the three main piles which are then drawn down to the fullest extent as shown by the appearance above them of pink rectal mucosa in the

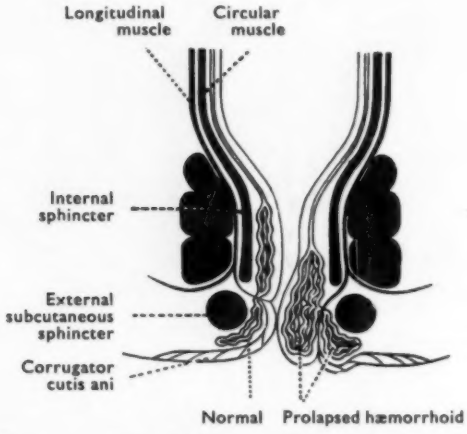

FIG. 60.—Milligan-Morgan concept of anatomy of hæmorrhoidectomy. *Stage I*: Pulling down of hæmorrhoid. Note that the internal and external sphincters are shown as retaining their normal relationship despite the traction on the pile. (*After Milligan and Morgan.*)

form of the 'triangle of exposure'. Taking each pile in turn, the skin of the anus and anal canal and the subcutaneous tissue in relation to it is divided with two scissor cuts. According to Milligan and Morgan these cuts divide the corrugator cutis ani and rapidly expose the lower or subcutaneous part of the 'external sphincter'. If the partly detached pile be drawn forcibly to the opposite side and its cut outer aspect examined there are seen to extend into it from the region just medial to the 'subcutaneous external sphincter' numerous longitudinal fibres. Milligan and Morgan claimed that these are the lower end of the main longitudinal anal intermuscular septum on its way to be attached to the anal skin. The ligature which is now applied to the pedicle of the pile includes these fibres, which according to these authors have descended on the outer side of the internal sphincter, and also the mucosa, submucosal connective tissue, and hæmorrhoidal vessels which descend on the inner side of this sphincter (*Figs.* 60, 61). They consequently believed that when it is tied, the ligature hitches on the lower edge of the internal sphincter and is thereby prevented from riding up into the anal canal.

In their description of the structures encountered during hæmorrhoidectomy Milligan and Morgan have apparently assumed that the anatomy of the anal region is exactly as shown in longitudinal sections of the anal canal (*see Figs.* 52, 60, 61) and as found on clinical examination of the unanæsthetized subject. The considerable distortion of the anal canal that occurs during the operation has been completely overlooked. Owing to the intimate connexion of the longitudinal fibres of the anal intermuscular septum and the musculus submucosæ ani with the internal sphincter, the initial traction on the hæmorrhoids exerts a pull on this sphincter and drags it down the anal canal to the anal orifice (*see Figs.* 62–64). Meanwhile, owing to the effects of the anæsthetic, the lower end of the external sphincter relaxes and moves laterally under the perianal skin outside the field of operation. We have established

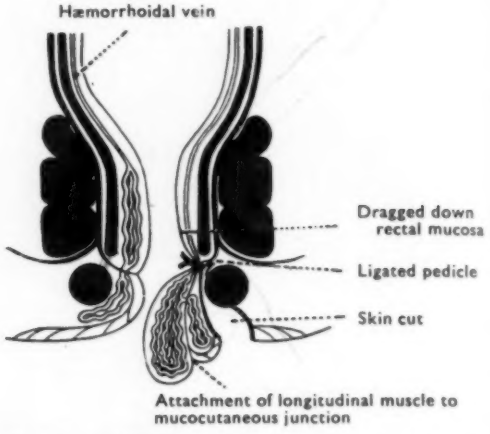

FIG. 61.—Milligan-Morgan concept of anatomy of hæmorrhoidectomy. *Stage II*: Isolation and ligature of hæmorrhoid. Note that skin cut exposes the lower edge of the external sphincter and that the main ligature approximates intermuscular longitudinal fibres and the mucosa at the lower border of the internal sphincter and is thereby prevented from riding up in the anal canal. (*After Milligan and Morgan.*)

that these sphincteric displacements do occur during hæmorrhoidectomy, by taking the simple precaution to identify and label the lower edges of the two sphincters immediately before commencing the operation, and also by making histological sections of the structures encountered during operation. The procedure which we have adopted in 12 cases, was as follows:—

The patient was brought to the theatre unanæsthetized in order to maintain the normal tone and contractility of the anal musculature and permit of the ready recognition of the sphincters on palpation. The lower edge of the external sphincter was first identified. Two small cutaneous weals were raised by intradermal injection of a few minims of a 1 per cent xylocaine solution above and below the muscle band and a stay suture was passed on a small curved cutting needle through the lower part of the muscle (*see Fig.* 65). In 6 of the cases the inferior border of the internal sphincter was also identified by palpation and similarly under-run by a marking suture, but in the other cases this was found to be technically too difficult in the conscious patient. Having inserted the identification sutures the patient was then anæsthetized with pentothal, gas, and oxygen. Finally, to ensure a bloodless field during the operation and thereby greatly facilitate the dissection, 30 c.c. of 1 per cent xylocaine containing 1–80,000 adrenaline hydrochloride was injected into the perianal subcutaneous tissues. The three main internal hæmorrhoids were grasped with forceps and pulled down in the usual way. The isolation of the left

lateral pile was then commenced by dividing the skin of the anus and anal canal on its outer aspect.

Immediately under the skin lies a layer of radially arranged fibres, closely attached to it. These are normally divided by the initial cutaneous incision, but can be clearly demonstrated if the skin is dissected up as a thin flap. When these fibres are severed, a plane of cleavage is entered, so that the external part of the hæmorrhoid can be stripped medially with ease, though a few isolated fibres may still need to be divided. At a point which corresponds to the interval between the external and internal components of the hæmorrhoid a well-marked bundle or sheet of longitudinal fibres is encountered which blocks further progress. When this is divided the hæmorrhoid can be pulled farther downwards and medially and a circular band of muscle comes into view (*see Fig.* 66). This is the structure identified by Milligan and Morgan in their account of the operation, as the subcutaneous external sphincter. It is to be noted, however, that this edge of muscle is white in colour and that it is not included in the stay suture which was introduced into the clinically palpable lower end of the external sphincter before anæsthetization of the patient and which now lies lateral to the wound under cover of the perianal skin. Enlargement of the wound in an outward direction demonstrates the actual edge of the external sphincter as a fairly flat band of muscle of reddish colour like any other voluntary muscle (*see Fig.* 67). Histological examination of biopsy specimens from this muscle show that it is composed of striped muscle-fibres, whilst sections of the previously identified paler sphincter muscle invariably reveal plain muscle-fibres. *There is no doubt that this latter is the rounded lower border of the internal sphincter.* Owing to the loose arrangement of its constituent muscle-bundles it is possible with very little scissor dissection to separate the lowermost ¼ in. or so of the internal sphincter as a discrete ring of muscle (*see Fig.* 68), which may be the reason why Milligan and Morgan postulated that the inferior or subcutaneous part of the external sphincter—as they imagined it to be—was a distinct bundle of muscle.

Medial to the internal sphincter, and running into the hæmorrhoid mass, more longitudinal fibres are seen. These are the lower part of the musculus submucosæ ani of Fine and Lawes. If the hæmorrhoid

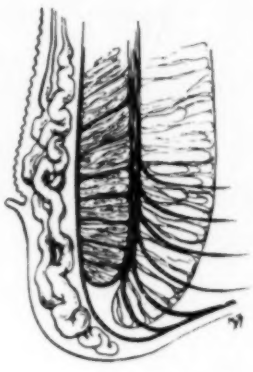

FIG. 62.—New concept of anatomy of hæmorrhoidectomy. *Stage I*: State of anal canal in unanæsthetized patient.

FIG. 64.—New concept of anatomy of hæmorrhoidectomy. *Stage III*: Isolation and ligature of hæmorrhoid. Note that as the skin cut is deepened it divides the longitudinal fibres which curl around the lower edge of the internal sphincter and thereby exposes this muscle and *not the external sphincter*. The pile ligature which is then applied is tethered by the attachment of the musculus submucosæ ani to the internal sphincter by numerous fibres proceeding between the bundles of the latter muscle.

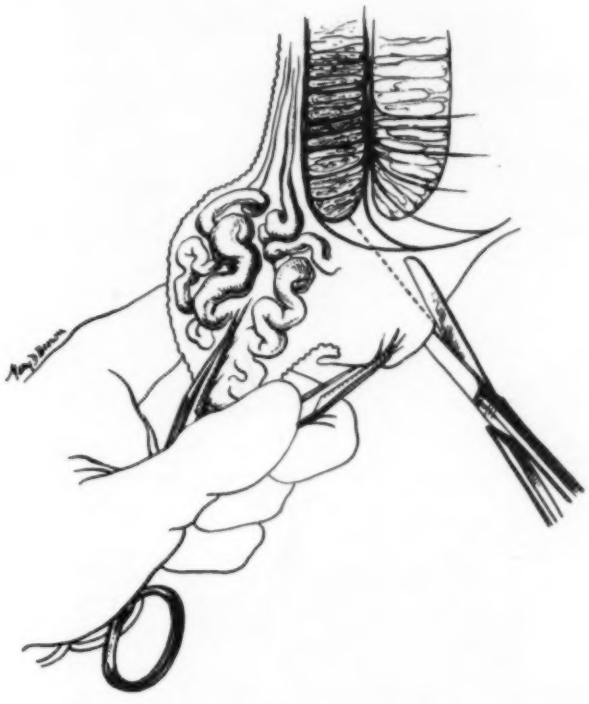

FIG. 63.—New concept of anatomy of hæmorrhoidectomy. *Stage II*: Patient anæsthetized and hæmorrhoid pulled down. Note that traction on the pile causes the internal sphincter to descend to the anal orifice, the lower edge of the external sphincter meanwhile relaxing and moving outwards.

is pulled downwards and medially and the internal sphincter gently retracted laterally these longitudinal fibres may be seen running upwards and outwards into the internal sphincter (*see Figs.* 64, 69). Just before they reach it a thin white transverse edge can be seen crossing them, looking rather like the edge of a hernial sac. This edge is formed by the inner fibres of one of the individual muscle-bundles of the internal sphincter. As has been noted in the histological sections of the anus, these muscle bundles overlap each other from above like tiles on a roof and their thin inner edges are attached to the submucous longitudinal fibres. As the longitudinal fibres are divided, the fibres of the internal sphincter drop back into line with their fellows. The arteries and veins of the hæmorrhoid lie medial to the internal sphincter amongst the submucous longitudinal fibres, and, provided one keeps close to the internal sphincter, dissection can proceed almost up the ano-rectal ring without encountering significant bleeding, although one would not of course dissect up in this layer during a routine hæmorrhoidectomy.

When the pile pedicle is ligated and the hæmorrhoid removed, the intimate connexion of the submucous longitudinal fibres with the internal sphincter anchors the ligature in the anal canal and prevents it from retracting up into the rectum (*Fig.* 65).

During Excision of an Anal Fissure.—The operation adopted here was that described by Gabriel (1948) in which the fissure is excised together with a generous triangle of skin, and "the subcutaneous part of the external sphincter" is divided at the apex of the resulting triangular wound. However, as a preliminary, before the patient was anæsthetized, the lower edge of the

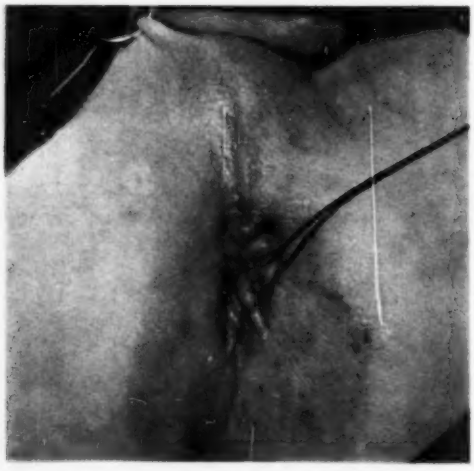

FIG. 65.—Identification of anal sphincters during hæmorrhoidectomy. Colour photograph showing stay suture introduced into clinically palpable lower edge of external sphincter before administration of general anæsthetic.

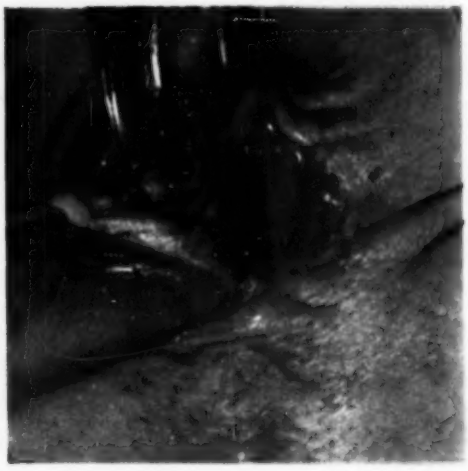

FIG. 66.—Identification of anal sphincters during hæmorrhoidectomy. Left lateral hæmorrhoid has been isolated by dividing skin on its outer side. The sphincter muscle exposed in the wound is the rounded lower edge of the internal sphincter; the external sphincter lies lateral to the wound, as is demonstrated conclusively by the position of the stay suture.

FIG. 67.—Exposure of anal sphincters during hæmorrhoidectomy. Extension of the wound laterally with further dissection to display the inferior border of the external sphincter, grasped by the stay suture, lying outside the internal sphincter.

FIG. 68.—Exposure of anal sphincters during hæmorrhoidectomy. Further view of the lower edges of the internal and external sphincters, showing how the inferior portions of these muscles may be easily separated by blunt dissection to convey the impression of a separate ring of muscle.

external sphincter was marked by a stay suture as in the hæmorrhoidectomy cases. In these patients with anal fissure there was generally too much anal spasm and pain to permit of labelling the lower margin of the internal sphincter. Finally, general anæsthesia was induced and the perianal tissues were infiltrated with a xylocaine-adrenaline solution.

The triangular incision is made approximately 1½ in. from apex to base, and, starting at the base, the flap of skin is dissected up as thinly as possible. The longitudinal fibres of the corrugator cutis ani radiating backwards and outwards from the anus are immediately exposed, and as the flap is further elevated it is seen that many of these fibres are attached to it, whilst others proceed farther posteriorly beyond the base of the wound. The raising of the skin-flap up to the actual fissure is now completed. It is found that the floor of the fissure usually consists of circular muscle, and if the longitudinal fibres that partly cover over this muscle on either side of the fissure are dissected away it is seen that the muscle underlying the fissure is the internal sphincter (*see Fig.* 70). Its pale rounded lower edge comes down to a point slightly distal to the actual fissure. The skin-flap is now turned upwards and the floor of the triangular wound inspected. So far the external sphincter has not been clearly seen, but if traction is exerted on the stay suture that was inserted into the lower edge of this muscle immediately pre-operatively a curved ridge is raised up running across the wound slightly nearer to its base than its apex. If the corrugated fibres covering this ridge of the external sphincter are dissected away it is seen to consist of a broad band of reddish voluntary muscle, roughly triangular in shape because of the backward extension of some of its fibres towards the coccyx (*see Fig.* 71). Finally, the skin-flap and fissure are excised and a Sims's speculum is introduced into the anal canal and lifted firmly upwards. The lower edge of the internal sphincter is rendered specially prominent by this manœuvre and behind it lies the much broader inferior portion of the external sphincter (*see Fig.* 72).

It is clear, therefore, that the sphincter muscle that has usually been divided in the course of the Gabriel type of fissurectomy in the past has been the lower edge of the internal sphincter, which, as in the operation of hæmorrhoidectomy, has been misinterpreted as the subcutaneous part of the external sphincter. In fact, the lower edge of the external sphincter is not deliberately divided at all in this operation, though it may occasionally be severed inadvertently by further backward incision of the floor of the wound with the scalpel as is often done to secure a smooth surface unmarked by any ridges.

Relationship of So-called Pecten Band to Anal Fissures.—Special mention must be made of the views of Ernest Miles on the relationship of anal fissures to the anal sphincter musculature. Originally he endorsed the popular opinion that anal fissures rested on and were associated with spasm of the external sphincter and that in treatment this must be overcome by stretching or division, care however being taken to avoid injury to the internal sphincter for fear of producing incontinence (Goodsall and Miles, 1900). Subsequently he apparently changed his mind and became convinced that the fissure lay not on the external sphincter, but on a circumferential flattened or rounded band of fibrous tissue situated between the skin of the lower part of the anal canal and the sphincter musculature. This he named the 'pecten band' and stated that it could always be felt on digital examination in the lower part of the anal canal in fissure cases and in many other patients as a firm ring rather like the rubber

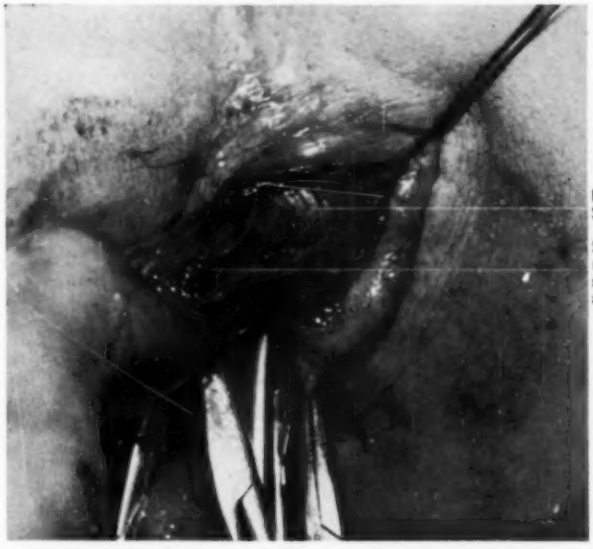

FIG. 69.—Exposure of musculus submucosæ ani during hæmorrhoidectomy. Photograph shows the longitudinal fibres of this muscle on the outer aspect of the isolated pile pedicle.

ring of an umbrella Miles (1918). In our experience this is exactly the sensation imparted by the lower end of the internal sphincter when it is well developed or in spasm in association with an anal fissure, and we suggest that what Miles called the pecten band was really the rounded inferior border of this muscle. We are further supported in this belief by the failure to find any undue condensation of the connective tissues underlying the pecten in any of our histological sections of the anal canal, though admittedly none of our specimens were derived from patients actually suffering from anal fissure.

In treating fissures Miles stressed the necessity for dividing this pecten band, usually not through the fissure itself, but posterolaterally, and considered that this was all that was required to secure inevitable healing. His last book on rectal surgery (Miles, 1939) contained a drawing of the 'pecten band' exposed at the operation of 'pectenotomy'. It is shown as lying just internal to the lowermost part of the external sphincter in exactly the same position as that occupied by the lower border of internal sphincter in our dissections, and it exhibits the pallor and other features of that muscle. A histological section of tissue from this 'band' would of course have immediately settled whether it was composed of fibrous tissue or plain muscle, but we have been unable to discover any report of histological findings in Miles' writings on the subject.

During the Perineal Dissection for Excision of the Rectum.—To secure further information

about the anatomy of the external anal sphincter, a special dissection was carried out in 4 patients during the perineal phase of an abdomino-perineal excision for rectal carcinoma, situated high in the bowel, well away from the sphincter region. This differed from the usual perineal dissection in that it was carried close to the anal canal and levator muscles

FIG. 70.—Exposure of anal sphincters during fissurectomy. *Stage I*: Triangular flap of skin dissected up to fissure, exposing the lower part of internal sphincter to which the fissure is adherent.

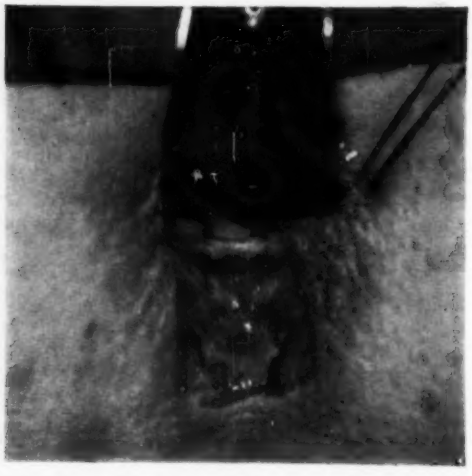

FIG. 72.—Exposure of anal sphincters during fissurectomy. *Stage III*: Skin and fissure have been excised, leaving triangular wound. A speculum has been introduced into the anal canal, rendering the lower edge of the internal sphincter especially prominent. The external sphincter is seen lying behind this in the middle and basal parts of the wound.

to permit of a close inspection of their outer aspects. The incision was made immediately surrounding the anal orifice; two parallel incisions running ¾ in. on either side of the median anteroposterior plane were then added in front and behind, as in *Fig.* 73.

The skin edge external to the circular incision and the forward and backward extension was dissected laterally to uncover the lower edge of the external sphincter and the perianal fat. Before the sphincter was actually exposed a layer of radiating longitudinal fibres had first to be divided. Some of these passed superficial to the sphincter and some emerged between its muscle bundles. The lower end of the external sphincter presented as a flattened rather than a rounded band of red voluntary muscle about ½–¾ in. wide on the lateral aspect of the anus.

The dissection was then carried upwards, hugging the outer side of the external sphincter, a close watch

FIG. 71.—Exposure of anal sphincters during fissurectomy. *Stage II*: Skin-flap turned upwards, revealing the external sphincter as a broad band of muscle, triangular in shape because of the backward extension of some fibres towards the coccyx.

being kept for any indication of a separation of the muscle into natural subdivisions or for any fascial or longitudinal muscular septa proceeding laterally from the sphincter. Several thin fascial layers were encountered in the fat around the anus, a more marked one being present about ¾ in. from the skin surface and serving to separate the finely lobulated fat of the perianal space from the coarser fat of the ischiorectal space. But none of these layers corresponded to any cleavage of the muscle substance of the external sphincter and biopsy showed that they contained no muscle. Dissection then proceeded through the ischiorectal fat until the inferior hæmorrhoidal vessels were met running medially into the upper part of the anal canal. Shortly above this the under aspect of the levator muscle was encountered, forming the pelvic diaphragm. As one surveyed the lateral aspect of the anal canal, without paying regard to the arrangement of the muscle-fibres anteriorly or posteriorly, it was quite impossible to say where the external sphincter ended and the pubococcygeus or puborectalis began.

The attachment of the musculature in front and behind the canal was now examined. To this end the longitudinal strips of skin outlined anterior and posterior to the anus were dissected up. This revealed that near the midline anteriorly and posteriorly the perianal skin is a major attachment of the lowermost part of the external sphincter. At a slightly higher level the external sphincter fibres formed the anococcygeal raphe which runs backwards to be attached to the dorsal aspect of the coccyx. Above this raphe the external anal musculature is devoid of posterior attachment, but forms a loop of muscle round the back of the canal. This

unfixed, free-lying, part of the anal musculature extends up to the level at which the median raphe of the pubococcygeus inserts on to the front of the coccyx. Between this upper raphe of levator and the lower anococcygeal raphe formed by the external sphincter there lies a space behind the anal canal filled with fatty tissue—the sub- or retro-sphincteric space of Courtenay (1949). The muscle which loops around the back of the anal canal may be wholly

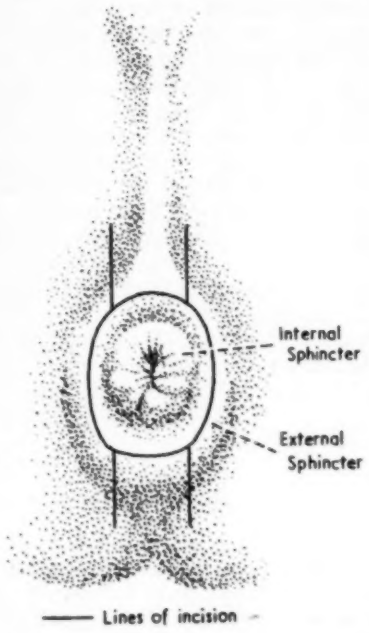

FIG. 73.—Outline of skin incisions used for modified perineal dissection during rectal excision to study anatomy of anal musculature.

external sphincter or partly external sphincter and partly levator ani. We find it impossible to make a clear distinction.

If the anterior attachment of the sphincter is now examined it is seen that many of the lower fibres are inserted into the perianal skin in and near the midline. At a higher level, corresponding roughly with the posterior attachment to the anococcygeal raphe, the external sphincter fibres merge with the transverse perineal muscles, by a process of decussation apparently in the region of the perineal body. Above this level most of the peripheral fibres of the external anal musculature seem to proceed forwards as puborectalis. Some of the more centrally placed fibres may of course encircle the anal canal anteriorly, but it is difficult to verify this in the course of a perineal excision because the anterior dissection is liable to sever such circular fibres. This is clearly a point that requires more detailed investigation than it has been accorded in this study.

CONCLUSIONS

1. The sphincter usually identified during operations for hæmorrhoids and anal fissures as the subcutaneous external sphincter is in fact the rounded lower margin of the internal sphincter.

2. Anal fissures lie on the internal sphincter not the external sphincter, and it is the lower part of the internal sphincter that is usually divided during operation for this condition.

3. The anatomy of the anal sphincters and longitudinal muscle-fibres in the anal canal differs in several respects from that described by most previous surgical writers.

4. There is no natural line of cleavage between the external sphincter and the levator muscles, and the anatomical distinction between these two structures would appear to be largely arbitrary.

We wish to acknowledge our great indebtedness to Mr. E. T. C. Milligan and Mr. C. Naunton Morgan for much helpful advice and criticism; and to the Research Department, St. Mark's Hospital, and to the Departments of Histology and of Medical Illustration, Postgraduate Medical School of London, for their valuable assistance in the preparation of specimens and illustrative material.

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PILONIDAL SINUS

A NEW THEORY OF ORIGIN

By ROGER BREARLEY, Liverpool

In 1945 Gage, who is an accepted authority on pilonidal sinus, wrote: "Everyone is in agreement that these cysts and sinuses are congenital in origin." To-day few British surgeons would accept this statement, yet it appeared at the time it was made to be securely based on factual evidence.

In subsequent years further observations have made an acquired origin seem much more likely, but so far no fully satisfactory theory has been put forward to explain the mechanism by which a pilonidal sinus originates. To offer such a theory, based on personal observation, is the principal object of this paper. The second aim is to re-examine the evidence upon which the theories of congenital origin rested, since this must be proved inadequate before such theories are rejected. Finally the likelihood is suggested that pilonidal sinus occurs in one other site where it has not so far been recorded.

HISTORICAL REVIEW

The history of this curious lesion and of the theories which have been advanced about it have been summarized by numerous writers (Rogers, 1933; Kooistra, 1942; Gage, 1935).

The first description was given by Anderson in 1847 in a paper entitled "Hair extracted from an Ulcer". Warren, in 1854, described an "Abscess containing Hair on the Nates". Hodges invented the term 'pilonidal sinus' in 1880. (*pilus* . . hair; *nidus* . . nest).

With the growth of embryological knowledge in the second half of the nineteenth century it is not surprising that a sinus in such a position should be suspected of arising from some fault of development, and from the time of Féré (1878) until Stone's paper in 1931 there were numerous publications propounding, investigating, discussing, and amending, but all supporting, this view. As to the nature of the malformation, three theories emerged.

1. Cystic remnants of the medullary canal persist in the sacrococcygeal region. These develop into a pilonidal cyst, which later becomes a sinus. This was the explanation of Tourneaux and Herrmann (1887), Mallory (1892), Gage (1935), and Kooistra (1942), amongst others.

2. Faulty development of the median raphe in the sacrococcygeal region leads to dermal inclusions which become pilonidal cysts and later sinuses. Féré (1878), Lannelongue (1882), Bland-Sutton (1922), and Fox (1935) adopted this view.

3. Pilonidal sinus is a vestigial structure homologous with the preen gland of birds (Stone, 1931) or a vestigial sex gland (Kallett, 1936).

The evidence which is held to support these theories will be discussed below. In the author's opinion it has always been inadequate, but it was widely accepted until Patey and Scarff in 1946 reported a case of pilonidal sinus in a barber's hand, attacked the theories of congenital origin, and suggested that it is ". . . primarily an infective lesion with secondary entrance of hair and debris, or the result of penetration of the skin by a hair which may also introduce both infection and epithelium". Since that time further reports have appeared of similar lesions in the hand (Patey and Scarff, 1948; King, 1949; Ewing, 1947), as well as in the following sites: axilla (Aird, 1952) perineum (Smith, 1948), beside the anus (under the name 'epidermal fistula of the perineum'—(Edwards and Riemann, 1950) and on a mid-thigh amputation stump (Shoesmith, 1953). Gillis's case (1954) could well be a further example, though histological details are not given. It has also been recalled that they were described by Hodges (1880) on the sole of the foot, and Aird quotes Jackson in the discussion following Warren's paper (1854) as describing one at the umbilicus.

MacLeod's (1953) case in the suprapubic region is not accepted by the author as a pilonidal sinus. From the description it was evidently a typical dermoid cyst but the interdigital webs of the feet are suggested as a further site in which the condition will be found.

NATURAL HISTORY OF THE LESION

Before considering the merits of opposing theories it is well to review the accepted facts which any satisfactory theory must explain. (Where not otherwise attributed, the facts are taken from Kooistra's review of 350 cases.)

Average age of onset of symptoms: 21½ years.

Average age of admission to hospital: 25 years.

Age distribution: Few under 17 years, great increase to maximum at 19, continuing high to 25, then steep falling off.

Sex: 73·7 per cent males.

Effect of sex on age incidence: Females were affected at a slightly earlier age; 40 per cent had symptoms before 20 compared with 19 per cent of the males.

Race: Considered very rare in negroes.

Bodily type: Dark hairy subjects constitute the majority, though not the whole of the cases. It is much rarer in blondes. (Oldham, 1950.)

Trauma: Riding in bumpy vehicles for long periods is an exciting factor (numerous authors).

Site: Pilonidal sinus in the sacrococcygeal region was until recently the only form known. Identical lesions in other sites listed above have now been described. They are smaller than the average sacrococcygeal lesion, and very rare.

Associated congenital defects including spina bifida are rare (Ferguson and Mecray, 1937). Kooistra gives a figure of 1·8 per cent.

Defective hygiene has been alleged to promote the condition (Holman, 1946). This is open to doubt.

Results of various forms of excision: Even very wide excision may be followed by recurrence in around 20 per cent of cases (Rogers, 1933; Block and Greene, 1938). Depilatory doses of X rays improve the results (Turrell, 1940; Carvalho, 1945).

Pathological Anatomy of Excised Sacrococcygeal Lesions.—

Macroscopical Appearance (*Fig.* 74).—

1. *The primary track*: Every pilonidal sinus has a primary track. It opens on the middle line, often through a very minute opening which is not certainly identified until it has been tested with a probe. Sometimes there are multiple primary openings of this kind for a distance up to 1 in. The primary track passes cephalad and deep into the fat over the sacrum for a distance seldom more than 2 in. It may terminate in an expanded cavity. When multiple primary openings are present they lead into the same primary track.

2. *Hairs*: Hairs may be seen protruding from a primary sinus, or they may be found within the track when this is laid open. Kooistra (1942) and Patey and Scarff (1946) found them in about one-half of their cases. It is not clear whether Patey and Scarff's figure is derived from clinic, operating theatre, and pathology department combined or from the last only. If it is from the last, it is surprisingly high, since most surgeons finding hairs immediately pull them out to display to the bystanders, leaving few for the pathologist to discover. Kooistra's figure is from the pathology department only. When present, hairs are never attached within the sinus, and if free are usually tapered at both ends like shed hairs. They may be growing from the skin outside the sinus, which may be situated at the centre of a hair node, so that the hairs naturally converge on it, as shown in *Fig.* 74.

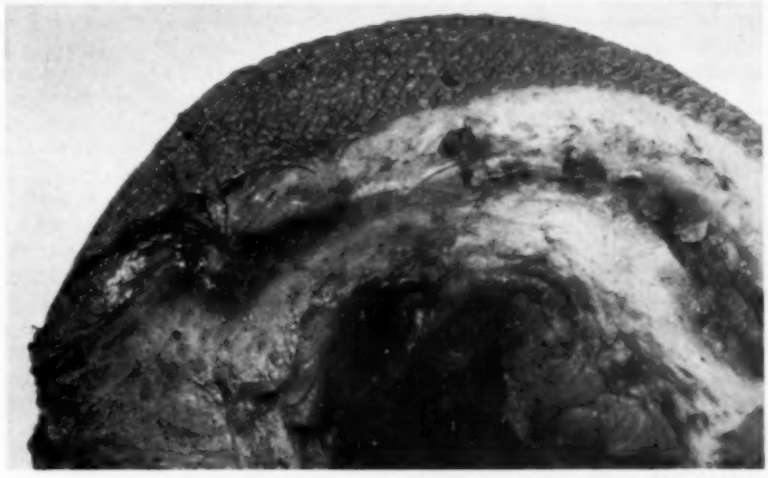

FIG. 74.—Typical pilonidal sinus in longitudinal section, showing hair node with tips of the hairs converging on the sinus opening.

3. *Secondary tracks*: In some cases there may be one or more secondary tracks. They originate from the deep part of the primary track and open on the skin to one side of the midline by an orifice from which exuberant granulations may be pouting. Sometimes a secondary sinus closes spontaneously though the track below it remains as a side shoot of the primary track.

Microscopical Appearance.—

1. *Lining.* It is generally agreed that secondary sinuses when present are lined with granulation tissue. They are the routes by which abscesses arising in the deeper part of the primary track have pointed and discharged. It is usually stated also, even by the supporters of the congenital malformation theories, that the cavity at the deep end of the primary sinus is lined with granulation tissue. (Kooistra, 1942). It is in respect of the wall of the primary sinus and the relation to it of the hairs in the track that accounts vary. Most authors agree that both squamous epithelium and granulation tissue are found and that granulation tissue is usual in the deeper part and squamous epithelium nearer the surface. In none of the articles listed in the bibliography is any definite statement made about the usual length of the segment lined by epithelium and that lined with granulations. Patey and Scarff (1946) found an epithelial lining in only 8 out of 21 cases. They infer that it was found in the more superficial part of the track but do not state its extent. Sheehan (1953) states that he has never known it to extend more than 2 mm. from the cutaneous opening in over 200 cases.

2. *Dermal appendages*: Multiple hairs are commonly found in the lumen of the primary track. Hair follicles in the wall are much rarer. Most of those alleged are open to doubt. In the articles listed in the bibliography illustrations of supposed follicles are occasionally given, but the author has been unable to find one showing an absolutely indisputable follicle with a hair growing from it. It may be added that when a primary sinus is laid open any hairs found within are not only free at both ends but usually so situated that neither end is in relation with the first 2 mm. to which the epithelial lining is confined. Illustrations of sweat and sebaceous glands are for the most part equally unconvincing. Patey and Scarff did not find any, nor did Sheehan.

CRITICAL ANALYSIS OF THE THEORIES OF CONGENITAL ORIGIN

1. The Preen Gland Theory.—This theory was put forward by Stone in 1931. He relates that in casual reading he discovered the existence of the preen glands of birds. As it is a sort of crypt situated near the anus he suggested that pilonidal sinuses may be vestigial preen glands. No evidence and no logical argument were adduced in support of this suggestion, and it is not proposed in this article to give it further serious consideration.

2. The Medullary Canal Vestige Theory.—Recent advocates of this theory include Gage (1935, 1939), Rogers (1933), Cattell and Stoller (1932), and Kooistra (1942), whose publications also summarize earlier work in support of this view by Tourneaux and Hermann (1887), Mallory (1892), and Oehlecker (1926).

Gage (1935) describes four types of pilonidal sinus:—

First type—sacrococcygeal dimple.—This occurs close to and slightly above the tip of the coccyx. It is a wide funnel-shaped depression of the skin in a caudal direction due to traction by the caudal ligament which connects the skin to the tip of the

coccyx. It disappears if the ligament is divided with a tenotomy knife. Often it is associated with a displaced coccyx.

Gage correctly states that this lesion is a different entity from pilonidal sinus, though he points out that a sinus may be found at the bottom of it. This he calls 'dimple sinus' in his 1939 paper. Sacrococcygeal dimple and not pilonidal sinus is probably the lesion for which Lawson Tait (1877) suggested an origin in the involution of the tail—probably the correct explanation. Newell's term (1933) 'traction dermoid' seems to be based on the confusion between sacrococcygeal dimple and pilonidal sinus.

Second type—true pilonidal sinus.—This is the condition which has been fully described above.

Third type (no distinguishing name given).—This type "extends down between the sacrum and coccyx, or enters the sacral canal for varying distances even extending to the dura at the level of the second sacral vertebra. The site of the cutaneous opening of the sinus varies in position but corresponds to the closure defects of the bony covering of the sacral vertebræ" (Gage, 1935). Gage then describes an example, with photomicrographs. It is a sinus lined with squamous epithelium. Neuroglial tissue is lying just outside it. It contains no hairs and was removed from within the sacral canal at a second operation having been incompletely removed previously.

Fourth type (no distinguishing name given).—The sinus communicates with the central canal of the spinal cord and discharges cerebrospinal fluid. Gage has no personal cases of this kind, but quotes two from the literature. Kooistra in 1942 could only find 14 recorded examples.

Gage considers that in describing his four types he has produced conclusive evidence "to show that pilonidal sinus results from an anomalous development of the medullary canal . . ." Kooistra draws the same conclusions from his embryological studies. Neither author, however, connects his conclusions to the observed facts by any logical argument. Gage's case may be considered first. This is the argument from a logical series. It implies that two lesions are different degrees of the same condition and not different conditions when a series of intermediate lesions can be found filling all the gradations between them. Only the second, third, and fourth types need be considered, as Gage admits that the first type is an entirely unrelated condition. The features of the second type (typical pilonidal sinus) need no further repetition. The fourth type, besides its extreme rarity, differs in other important respects from pilonidal sinus. Both the cases quoted by Gage (Moise, 1926; Ripley and Thompson, 1928) had lesions which were obvious at birth. In Moise's case the opening was over the first sacral vertebra and there was sacral spina bifida. The patient died at 18 years from staphylococcal meningitis. Ripley and Thompson's patient was 3½ months old. Death from staphylococcal meningitis followed excision of a track extending 2½ in. down from the lumbosacral joint. It was lined with skin and contained hairs. Shenkin, Hunt, and Horn described a similar case in 1944. Their patient died at one year and ten months having had a sinus from birth. It is not stated at what level the sinus was situated. Their Fig. 1 makes it appear that the skin opening was at about the level of the third sacral vertebra. The features of this type, therefore, seem to be a sinus present from birth, lined with skin, opening on the middle line of the back high in the sacral region, sometimes exuding cerebrospinal fluid and passing down to the medullary canal through a spina bifida. There is a high risk of death from meningitis in early life and the lesion is very rare.*

The third type is even rarer, for Gage's case is unique. He published it in 1935, but has never published a further example although it seems probable that he would have kept a sharp lookout for examples of what he evidently regards as the missing link between the second and fourth types.

No description is given of the original appearances of the lesion as the patient had had a previous operation. It would have been interesting to know whether the sinus originally opened in the sacrococcygeal region like a pilonidal sinus or higher up as in the fourth type. The finding of an epithelial track within the sacral canal is suggestive of the fourth type and it seems probable that the case was of this kind but with a portion of the track between the sinus and the medullary canal obliterated. There can be no proof that this great rarity is a form of the common pilonidal sinus, and indeed every circumstance seems to suggest the reverse.

Kooistra reviews his own histological studies of the sacral region of the human embryo which confirm the findings of earlier students.

He shows that remnants of the medullary canal overlying the coccyx undergo a natural process of degeneration and form cysts lined with epithelium resembling ependyma. These cysts normally degenerate and disappear during the second half of fœtal life.

The argument implied is of a different kind. It may be reduced to the form of a syllogism.

1. Epithelial lined cystic remnants of the medullary canal occur beneath the skin of the sacral region in embryonic life.

2. Pilonidal sinus communicates with a partly epithelialized track in the same situation in adults.

3. Therefore pilonidal sinus is derived from these cystic remnants.

It will be seen that the premises do not warrant the conclusion.

The cysts in question are lined with cuboidal epithelium resembling ependyma and not skin. This is admitted by Kooistra in the legend to his Fig. III, in which it is clearly shown. In this

* Four contributions requiring comment have appeared since this paper was written. Weal (1955) describes a histological method showing the polarity of shed hairs. In seven sinuses which he examined he found hairs with their root ends pointing cranially, and deduced that they must have grown there. This is not the only possible explanation. Patey and Scarff (1955) point out that because of the arrangement of its scales, a hair tends to travel root first when rubbed to and fro along its long axis. The argument is settled by the finding that the root end does not always point cranially (author's Cases 1 and 2), and that sometimes the sinus contains other foreign bodies, such as grass (Page, 1955).

Finally, Howarth and Zachary (1955) have described a series of sinuses in children, resembling Gage's fourth type. Their cases illustrate the differences already commented on between this type of lesion and the pilonidal sinus.

connexion the opinion of Streeter, whose authority on embryological matters is beyond question, seems final. Stone (1924) quotes him as saying that the epithelium of the coccygeal medullary vestige is already so far differentiated that if it persisted it could not be expected to give rise to skin.

3. The Inclusion Dermoid Theory.—Fox (1935) supported this theory. He studied the sacral region of seven embryos by histological methods. His illustrations show the skin to be thrown into wrinkles (the possibility that this is due to fixatives is not discussed). Some hair follicles are seen developing as downgrowths of the epithelium. No true cysts or sinuses are seen, although the absence of subcutaneous fat in embryos makes any epithelial downgrowth look close to the sacrum. Bland-Sutton (1922) offers no proof that pilonidal sinus (a term which he does not use, though it is obviously the entity referred to) arises in this way. He merely asserts it.

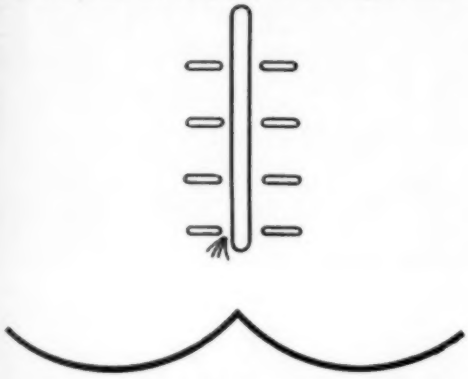

FIG. 75.—Recurrent pilonidal sinus. Hairs still attached at their roots are converging on a small drill hole which they have made.

If this theory were true the sequence of events to be expected would be, a cyst present from birth, possibly small at first with a tendency to enlarge, followed later in some but not all cases by infection, suppuration, and the discharge of cheesy material, hairs, and pus, probably to one side of the midline. (Any abscess arising over the sacrum tends to point lateral to the midline because of the attachment of the skin to the deep fascia at that point: the secondary tracks of a pilonidal sinus demonstrate this.) One would expect the cyst to be often recognized and removed before the occurrence of infection. After suppuration one would expect to find epithelium in the deeper part of the track rather than the outer part. This sequence of events has never been observed. Fox (1935), whose paper supports the dermoid theory, expressly states that the 'cyst' (that is the expanded deeper part of the sinus) has no epithelium and the hairs are not growing from it, some even lying in the stroma surrounded by giant cells. He goes on: "nowhere does one see the characteristic circumscribed structure of a dermoid. In fact I have never seen a pilonidal sinus contain the cheesy substance or the compressed epithelial lining and keratin centre of an epidermoid or subepithelial dermoid cyst."

To sum up, the theories of congenital origin are unproved speculations, they do not explain the known facts of the condition, and being based on embryological peculiarities of the sacrococcygeal region must be rejected now that pilonidal sinus is known to occur in other situations. There are, however, certain lesions of the sacrococcygeal region which in the past have been confused with pilonidal sinus. Some of these are congenital, including a variety of cystic conditions in the pelvis and perineum described by Raven (1935) and medullary canal fistulæ (*see above*). None of these resembles a pilonidal sinus. The similarity is closer when a postrectal dermoid suppurates and points posteriorly lateral to the coccyx (Ferguson and Mecray, 1937) and even closer in hidradenitis suppurativa, an acquired condition with a similar distribution (Conway, Stark, Climo, Weeter, and Garcia, 1952).

PERSONAL OBSERVATIONS

Case 1.—In 1952 the author operated on a young male adult excising an ellipse of skin 2½ × 1½ in. with underlying fat down to the sacral fascia, surrounding a short primary pilonidal sinus track containing hairs. The excision appeared to be complete and the wound was closed by primary suture. It healed by first intention and was perfect at the time of discharge from hospital on the seventeenth post-operative day. Two months after operation the patient was seen at the follow-up clinic. The wound was slightly keloid and the body hairs had grown again. Towards the lower end of the wound the surrounding hairs converged on the scar which was at the bottom of the natal cleft and their free ends disappeared into a small sinus at the side of the scar (*Fig.* 75). The hairs were tweaked out and the sinus probed. It was about 2 mm. deep. The patient was instructed to remove all hairs from within 2 in. of the scar by applying a depilatory cream. In a fortnight the sinus had disappeared. He has continued to keep the part hairless and has been followed for six months without further sign of recurrence.

Case 2.—This patient, a man of 30 years, presented with an eight-year history of recurrent abscesses over the sacrococcygeal region. On examination, several scars were present lateral to the midline, together with a centrally placed primary opening from which a hair protruded. On pulling this it was found to be the free end of a hair the base of which was still attached to the skin a little way from the opening, part of the shaft being bent into a U which occupied the sinus.

Case 1 shows that the free ends of hairs still attached at their roots to the skin may converge on a sinus at the bottom of a natural cleft and enter it. As the sinus did not appear until the hairs had regrown after operation and disappeared again after epilation it seems probable that the tips of the hairs caused the sinus. When the patient visited the follow-up clinic the hairs were in fact caught red-handed.

Case 2 shows that hairs from the surrounding skin may enter an established primary sinus. Here the middle of the shaft had entered the sinus and folded itself in two in order to do so. It is difficult to imagine this occurring unless it had been sucked in. Patey and Scarff (1948) have already suggested this possibility, and Sheehan (1953) also believes that it occurs.

It is therefore postulated that the sinus is initiated by the surrounding hairs puncturing the skin and forming a short track while still attached at their roots. After being shed, they are sucked in, further deepening it. It is proposed that the first stage should be called a 'puncture sinus' and the second stage a 'suction

sinus'. The evidence for this theory will now be considered more fully.

The Initiation by Puncture (Puncture Sinus).—There is no doubt that this can occur. *Case* 1 illustrates it, as do the cases in barbers' hands. Consideration of the sites in which pilonidal sinus may occur suggest the mechanism involved. The natal cleft and perineum, the interdigital webs, the axilla, and possibly the umbilicus, are all situations where a rolling movement takes place between two flat surfaces on either side of a cleft (*Fig.* 76). This twists the hairs into a bundle which lies along the bottom of the cleft and drills its way obliquely through the skin. *Fig.* 75 is thus explained. Since

FIG. 76.—Showing how natural movements of the buttocks produce a cigarette-rolling action.

pilonidal sinus occurs in only a small proportion of the population it must also require the co-operation of other factors, which probably include the stiffness of the body hairs, thickness of skin, configuration of the parts especially a well-formed hair node as shown in *Fig.* 74. In the cases involving glabrous skin (palm of a barber's hand, sole of the foot) the hair must be pushed through the skin like a pin. This can only happen with very short stiff hairs such as the fragments to which barbers are exposed.

This theory explains the known facts of the natural history of the condition as follows.

Age Incidence.—The disease starts after puberty because there are no stiff body hairs until then. After middle age the incidence falls steeply because the body hairs become softer and because those patients in whom local factors predispose to the disease will already have acquired it.

Sex Incidence.—73·7 per cent of Kooistra's cases were male. Men have more stiff body hairs than women. The age incidence is slightly lower in women. So is the age of puberty and therefore the appearance of body hair.

Site Incidence.—Although cases have now been described in other situations, the overwhelming majority occur in the sacrococcygeal region. At this point there is a node from which a tuft of hairs lying between two skin surfaces is rolled into a bundle converging on a point of the skin under which there are natural suction forces. Nowhere else in the body are all these factors to be found together in an equal degree. In the axilla and interdigital clefts and amputation stump there is no hair node, and indeed in the interdigital clefts no hair of local origin, but in all three there are rolling movements. The suction forces inside the bucket of an artificial leg are well known. The fact that abduction of the fingers and arm respectively cause suction forces in the web spaces and axilla is evident from the fact that their overlying skin is drawn in as these movements occur. The suction forces in the sacrococcygeal region are described below.

Race and Physical Type.—The disease is commonest in dark-skinned hairy individuals; blond Nordic

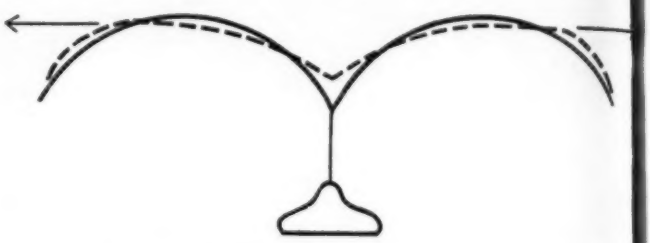

FIG. 77.—Showing how separation of the buttocks pulls the skin of the midline away from the sacrum, causing a suction force.

types are less affected (Oldham, 1950). They have less body hair and it is usually softer. In those cases with blond skin and little body hair observed by the author, there is always a stiff tuft of perianal hair pointing up the natal cleft. Negroes are rarely affected. They also have little body hair as a rule, and what they have is curly and therefore ill adapted to drilling.

Cleanliness.—Some writers (Holman, 1946) stress lack of cleanliness as an aetiological factor. It is easy to see how sweat and grease would help to bind a bundle of hairs into a more effective drill, and how washing would tweak the drill out of an early sinus, allowing it to heal. In the author's opinion this point is not very important. Many cases occur in patients of satisfactory cleanliness.

Results of Treatment.—After various forms of treatment the recurrence rates reported average about 20 per cent (Kooistra, 1942; Block and Greene, 1938). It is difficult to think of any other non-malignant cystic condition which recurs so readily after excision. *Case* 1 suggests the explanation. So-called recurrences are in fact new lesions arising in the same way as their predecessors. X-ray epilation is known to be of benefit (Turrell, 1940; Carvalho, 1945—no recurrence in three years with eight cases; Smith, 1937). Malthesheimer (1945), who used an open packing method, recommended keeping the part shaved during the healing period. It is generally agreed that in spite of its inconvenience wide excision and open packing gives better results than primary suture (Rogers, 1933). This is understandable since the prolonged presence of a wide granulating wound and the subsequent broad

midline scar fixed to the sacrum must greatly reduce the rolling movement of the buttocks and provide a hairless zone on either side of the midline. On the other hand, when a hair node has caused the hairs to converge, its excision might be sufficient to cure the condition. This may explain why an operation which fails in 20 per cent of cases succeeds in the other 80 per cent.

If the twist drill mechanism is the correct explanation it might be expected that pilonidal sinus

FIG. 78.—Tracing showing fall in pressure on separating the buttocks four times. 1 mm. on the scale represents 26 mm. water pressure.

would occur in the interdigital webs of the toes. The author believes he has seen such a case.

Case 3.—A girl of 18 years attended the surgical out-patient clinic complaining of an abscess on the foot. On separating the left great and second toes an abscess was found in the web. Between the toes was a bundle of short pieces of horsehair. The girl said she worked in a furniture factory upholstering chairs. She also said she knew other girls who had had a similar condition. Unfortunately she did not attend again and the diagnosis remains unproved.

The Enlargement by Suction (Suction Sinus).—The skin at the bottom of the natal cleft is attached to the underlying deep fascia in the way skin always is at a permanent crease (Wood Jones, 1920). Any force withdrawing the skin laterally across the buttocks puts tension on this fascial attachment and thereby creates a suction force within (*Fig.* 77). This is why the vigorous massage which is applied to the rear parts of those who ride in jeeps causes their pilonidal sinuses to give so much trouble. It is noticeable that the primary track always underlies the middle line, but never extends further cephalad than the gluteal cleft, since beyond this point the conditions of *Fig.* 77 cannot be produced. The author has measured this suction force by inserting a needle into the subcutaneous tissues of the gluteal cleft in the midline. The needle was connected by a system of tubing filled with normal saline to a capacitance manometer. The resultant tracing, *Fig.* 78, shows a sharp fall in pressure of about 80 mm. of water each time the buttocks were separated, followed by a slow recovery. In the tracing recovery is in each case incomplete at the time of the next separation, and the lowest pressure obtained after four separations is 210 mm. of water below the initial testing pressure.

Principles of Treatment.—If the above theories are correct more suitable and effective treatment should be possible in the future. Two requirements must be fulfilled; firstly, the prevention of drilling; and secondly, the cure of an established sinus by the methods applicable to sinuses anywhere in the body. The first may be effected by irradiation or possibly daily scrubbing in the line of the cleft after excision of the hair node, and the second by excision of the track followed either by closure and first-intention healing or open packing. It should no longer be considered necessary to create a gaping wound taking months to heal (Rogers, 1933), excise pieces of the axial skeleton, or move large pedicle grafts (Lahey, 1929).

SUMMARY

1. The various theories attributing a congenital origin to pilonidal sinuses are critically examined. They are considered to lack proof or probability, and to fail to explain the known features of the condition.

2. Evidence is presented in favour of an acquired origin.

3. A new theory is advanced concerning the mechanism by which this occurs (the puncture sinus and suction sinus theory). It is shown to conform to all the known features of the condition and to be supported by personal observation and experiment.

4. The interdigital webs of the toes are suggested as another possible site for the lesion.

5. Brief recommendations are made of the proper principles of treatment.

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INTESTINAL PNEUMATOSIS ASSOCIATED WITH ACUTE DILATATION OF THE STOMACH

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PNEUMATOSIS of the intestine, first fully described in man by Bang (1876), is a rare condition whose main feature is the presence of cysts in the subserous and submucous layers of the bowel. These are most common in the small intestine, particularly in the distal ileum, although the colon may be involved (Matthews, 1954). The condition has been reviewed by Mills (1925), Thoma and Henniger (1952), and Koss (1952). In a series of 213 cases which he found in the literature, Koss noted that 58 per cent occurred in the presence of obstruction at the pylorus, mainly due to peptic ulcer. Other associated conditions include intestinal obstruction, intestinal tuberculosis, and appendicitis. In most cases the time of onset of the condition cannot be stated with certainty, although in that described by Dale and Pearse (1950) the pneumatosis had occurred during the five weeks which elapsed between operation and death of the patient. The present report deals with a most unusual case in which pneumatosis occurred as an acute phenomenon in the course of a fulminating illness which proved fatal in 18 hours.

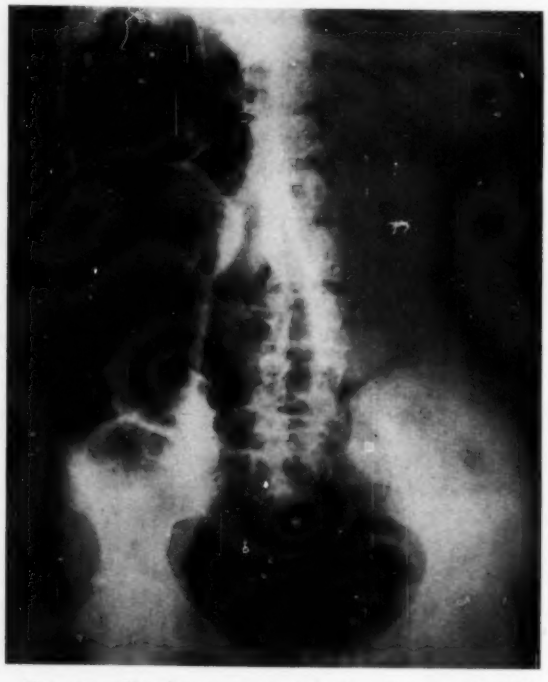

FIG. 79.—Showing gas apparently in colon on the right side of the abdomen with the patient in the supine position.

FIG. 80.—Showing an enormous collection of gas on the left side of the abdomen. Film taken with the patient in a semi-erect position.

CASE REPORT

A single woman, aged 50, in previous good health, was admitted to hospital in a moribund condition after having had severe generalized abdominal pain for 7 hours. This pain began shortly after a meal and was accompanied by repeated eructations and vomiting.

EXAMINATION showed a pale semicomatose woman suffering severe pain; the radial pulse was not palpable and there was no recordable blood-pressure. The most striking feature was the enormously distended abdomen, resonant to percussion. Two pints of dextran were

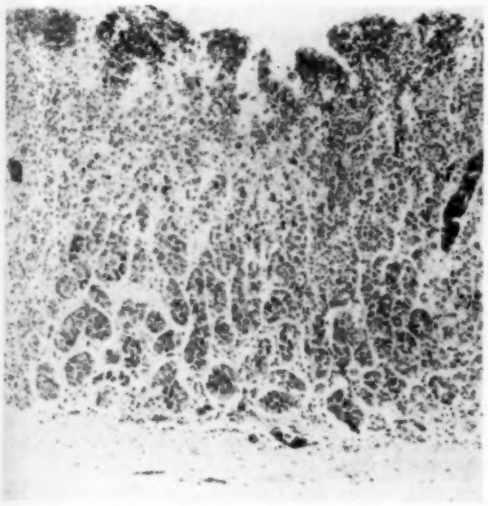

FIG. 81.—Congestion and hæmorrhage in the gastric mucosa. H. and E. (× 48.)

immediately given intravenously over a period of 15 minutes, after which the blood-pressure rose to 130/70. Only a very small amount of turbid gastric content could be removed through a Ryle's tube, and the distension was not relieved to any appreciable extent. Radiological examination of the abdomen suggested that an enormously distended portion of large bowel occupied the left half of the abdomen. A marked difference was noted between films taken in the supine and semi-erect postures (*Figs.* 79, 80). A provisional diagnosis of volvulus of the large bowel was made.

AT LAPAROTOMY the gross distension was found to be due to an acute dilatation of the stomach. Gastrotomy immediately relieved the distension and a few ounces of brown turbid fluid were removed from the stomach. A small thickened area was found in the pyloric region. At this stage a sickly sweet smell was very noticeable. The small intestine was slightly distended and its colour varied from areas which were very pale to others which were cyanotic, ranging in shade from lilac to dark purple. The colon appeared normal. On examination of the mesentery of the small intestine innumerable bubbles of gas were seen coursing from the bowel to the root of the mesentery in the mesenteric veins. They varied in size from some which were just visible to others of a diameter of 3 mm. The bubbles were most easily seen in the upper jejunal mesenteric veins. The mesenteric arteries appeared normal. As the patient's condition was critical the abdomen was closed, and a diagnosis was made of septicæmia due to anaerobic infection. Intravenous aureomycin was given and as the blood-pressure at the end of operation was 60/? a blood transfusion was commenced. However, there was rapid deterioration and death occurred 8 hours after operation.

NECROPSY, performed 21 hours after death, showed gross changes in the abdomen and chest. The stomach was enormously distended by gas and dark brown, bubbly, watery fluid containing undigested food and including large numbers of raisins. The stomach contents had a sweet smell. There was an oval, deep chronic ulcer, 2 × 1·5 cm., immediately proximal to the pyloric ring, its long axis perpendicular to the lesser curvature. Its floor was adherent to the pancreas. The mucosa of the stomach contained numerous minute bubbles of gas measuring up to 2 mm. in diameter. In the distal third of the stomach, the mucosa was red in colour, elsewhere it was dark brown. The proximal 2 metres of small intestine were slightly distended. The wall of the small intestine was congested and small

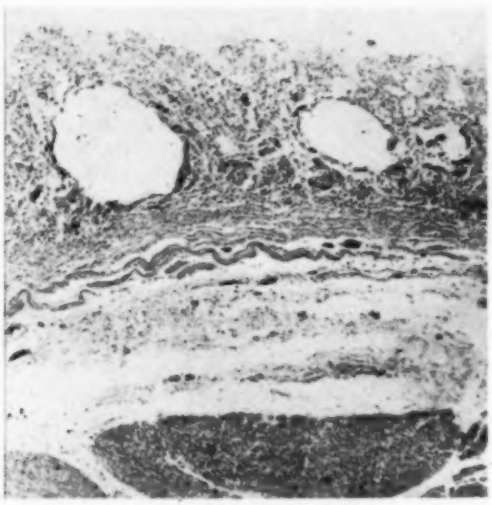

FIG. 82.—Gas bubbles occurring as clear spaces in the gastric mucosa. H. and E. (× 36.)

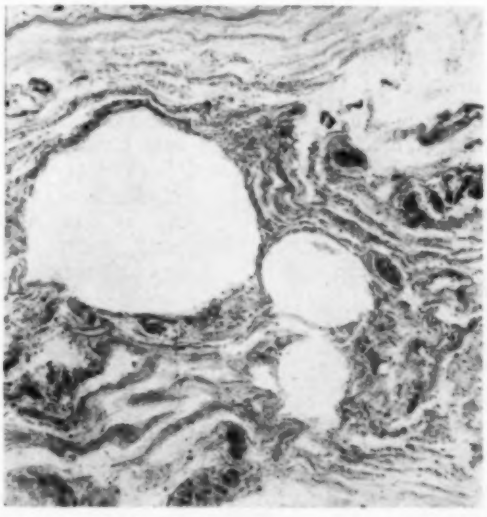

FIG. 83.—Gas bubbles in the submucosa of jejunum. H. and E. (× 48.)

hæmorrhages were scattered throughout the mucosa. In the mucous membrane of the duodenum and proximal part of jejunum there were numerous bubbles of gas identical in appearance with those seen in the gastric mucosa. The intestinal contents were of normal consistency, red-brown in the jejunum and yellow-brown in the ileum. Several small bubbles of gas were seen in the mesenteric veins. The only abnormality in the mesenteric arteries was slight atheromatosis. The liver showed only patchy pallor at the cut surface.

Blood-stained serous effusions were present in both pleural sacs. Brown mucus was found in the large bronchi and the lungs were partially collapsed, congested, and œdematous. In the lower lobes there were many areas of hæmorrhage.

Microscopic Findings.—The blood-vessels of the stomach and small intestine were congested and hæmorrhages were present in the mucosa (*Fig.* 81). Gas

spaces were seen as clear areas in the mucosa of the stomach (*Fig.* 82) and duodenum, and in the mucosa and submucosa of the jejunum (*Fig.* 83). The gas spaces were surrounded by either compressed glandular epithelium or connective tissue, or both. No endothelial lining was observed. No inflammatory reaction was present and giant cells were not seen.

Bacteriological Report.—Culture of the peritoneal contents at the time of operation yielded *Staph. albus* and *Str. fæcalis.* Specimens of blood from the heart and mesenteric veins, also specimens of stomach contents, all taken at necropsy, were cultured aerobically and anaerobically. No clostridia were found. The only positive findings were the growth of *B. coli* in small numbers from the mesenteric veins and *Staph. albus* from the stomach contents. Sections of the stomach and intestine were stained by Gram's stain and showed no organisms.

DISCUSSION

The immediate cause of death was the inhalation of stomach contents, which may have occurred prior to admission or after operation. The condition of acute dilatation of the stomach seemed to be closely related to the ingestion of a large amount of highly fermentable material in the form of a raisin cake. The presence of a juxtapyloric ulcer may have contributed by causing pyloric spasm. The pathogenesis of acute dilatation of the stomach remains obscure, but it is interesting to recall the condition of ' bloat ' in which a similar acute picture develops in cattle when grazed on clover. Heath and Park (1953) have reported the presence of a cholinesterase inhibitor in white clover which may have some bearing on the aetiology of this condition. The present case, at one stage thought to be one of overwhelming anaerobic infection, was similar in some respects to that of Kellert and Meeler (1953), who described a fatal case of *Cl. Welchii* gastro-enteritis which showed many small cysts in the intestine. These were, however, associated with a brisk leucocytic reaction and the presence of many Gram-positive bacilli.

The mechanism of development of the cysts in pneumatosis intestinalis remains uncertain. A similar condition occurs naturally in pigs, and was in fact known to John Hunter (Aird, 1950); it has been produced experimentally in pigs on a deficiency diet (Eveleth and Biester, 1938), but dietary factors seem unlikely to be important in man. Mechanical factors have been invoked, especially in those cases where there is a breach of intestinal mucosa; there still, however, remain the cases of primary pneumatosis where no associated lesion is found. Masson (1925) has suggested that the cysts are blocked lymphatics and that the gas is originally carbon dioxide arising from fermentation in the bowel; the gaseous contents of the cysts become modified by diffusion of nitrogen, oxygen, etc., from nearby blood-vessels. Gaseous exchange between the bowel and the blood-vessels has been studied by McIver, Redfield, and Benedict (1926). They found, in experiments on cats, that the quantity of gas which diffused across the bowel wall in unit time depended directly on the differences in partial pressure on either side of the membrane and the surface area involved, but inversely on the thickness of the membrane. Carbon dioxide diffused rapidly, oxygen more slowly, and nitrogen only to a very small extent. Pogrund and Steggerda (1948) obtained comparable results in their studies on the absorption of gases from the colon in man.

In this case an extremely vascular and extensive area of very thin stomach wall was available for gaseous exchange, with the presence in the lumen of a high partial pressure of a gas, almost certainly the easily diffusible carbon dioxide. These factors were presumably responsible for a high rate of absorption into the blood-vessels, and the intraluminal pressure of gas may have caused the development of the cysts in the tissue spaces of the gastric mucosa. It is unlikely that these cysts represent dilated areas in sinusoids or lymphatics as no endothelial lining was seen. The reason for the development of the gas bubbles in the veins is not clear. As the mesentery could not be seen at operation until deflation of the stomach, it is uncertain whether the rapid reduction of pressure in the abdomen at this time caused some gas held in the blood to come out of solution. Such an event would seem to be unlikely if our suggestion is correct that the gas bubbles were composed of a soluble gas like carbon dioxide, but less improbable if the gas were nitrogen.

The suggestion has been made (Stiennon, 1951) that the gas absorbed from areas of increased intraluminal pressure in the bowel may travel in the mesentery; this would explain the frequent occurrence of subserous cysts at some distance from any breach of mucosa, as by a peptic ulcer. In this case it was noted that the gas was travelling from the bowel in the mesenteric veins and none was seen in either the lymphatics or free in the mesentery.

SUMMARY

A report is given of a case where intestinal pneumatosis occurred in an acute form during the course of a fatal illness, in which the major feature was acute dilatation of the stomach. An unusual feature was the presence of gas in the mesenteric veins seen at operation.

We are grateful to Professors W. C. Wilson and J. S. Young for their advice, and to Dr. W. Hamilton for the bacteriological report.

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ELECTROLYTE CONTENT OF MUSCLE SAMPLES OBTAINED AT SURGICAL OPERATIONS

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In assessing the state of fluid and electrolyte metabolism in surgical patients it is sometimes insufficient to rely on information obtained by serum or urine analysis since these provide no direct evidence of changes within the cells, and there is a great need for some method of obtaining, more or less directly, information regarding intracellular composition. In recent years the technique of tissue analysis has been considerably improved and employed in patients with cardiac failure (Iseri, Alexander, McCaughey, Boyle, and Myers, 1952; Mokotoff, Ross, and Leiter, 1952; Talso, Spafford, and Blaw, 1953), in acidosis and alkalosis (Mudge and Vislocky, 1949), and following gastric aspiration (Ariel, 1954). There are few reports of the application of tissue analysis in the investigation of surgical patients. Winfield, Fox, and Mersheimer (1951) showed changes in muscle composition at the site of operation during the course of the operation and Eliel, Pearson, and White (1952) have described the muscle composition in a patient after eight days parenteral feeding and again eleven days following an extensive resection of a carcinoma of the ampulla of Vater.

MATERIAL

Twelve normal cases were studied in which there was no reason to assume the existence of any disturbance of fluid or electrolyte metabolism. The operations at which the muscle samples were obtained are shown in *Table I*. Sample 5 was obtained from the same patient as sample 6 but at the end of the operation. Only the water, fat, and solid contents of this sample are presented.

Biopsies were also obtained from a further 6 patients undergoing primary or secondary operations and in whom there was believed to exist some disturbance of fluid or electrolyte metabolism:—

Case 14.—Obstructive jaundice with prolonged vomiting, loss of weight, and malnutrition.

Case 15.—Pyloric stenosis with vomiting.

Case 16.—Hyperchloræmic acidosis following bilateral ureterosigmoidostomy.

Case 17.—Subphrenic abscess, vomiting, and gastrointestinal aspiration.

Case 18.—Carcinoma of the pancreas, in whom the mesentery and omentum were œdematous at operation.

Case 19.—Prostatic enlargement, cardiac failure, and œdema. The serum electrolyte concentrations were markedly reduced.

METHODS

1. Technique.—Muscle biopsies were obtained from the operation site as early as possible after the skin incision had been made, with the exception of sample 5 as described above. The samples were obtained from rectus abdominis on 12 occasions (in 1 case pyramidalis also was sampled), pyramidalis alone in 1, pectoralis major, internal oblique, external oblique, and latissimus dorsi 1 each, and erector spinæ in 2 cases.

At the same time as the muscle biopsy was taken blood was obtained for determination of the sodium, potassium, and chloride concentrations as described below for the muscle samples. The total protein content of the plasma was also measured.

The method of analysis is essentially the same as that used by others. The sample of muscle was prepared and weighed within five minutes of its being obtained. Excess blood was carefully blotted off, fatty tissue, if any, removed, and the sample cut into a number of small pieces. These were weighed immediately in a closed weighing bottle. The sample was dehydrated to constant weight on a water-bath and in a desiccator, fat was extracted by three or four changes of petroleum ether and the ether removed by further warming on the water-bath before the fat-free dry weight of the sample was determined.

Where the sample was large enough a small piece was taken for total nitrogen determination by the micro-Kjeldahl method, while the remainder was extracted by means of 10 ml. of 0·75 *N* nitric acid. Electrolyte concentrations were measured in this extract, chloride by Sendroy's method as modified by Van Slyke and Hiller (1947) and sodium and potassium by means of an internal standard flame photometer.

2. Calculations.—Extracellular concentrations were calculated from the plasma concentrations using a Donnan factor of 0·96 and assuming that the plasma water was equal to (1000 − grammes of protein/l.)ml./l. of plasma. Thereafter calculation of the phase volumes was carried out as described elsewhere (Hastings and Eichelberger, 1937; Talso, and others, 1953), with the exception that no correction was made for the solid content of the extracellular phase.

The extracellular space was calculated from the total tissue content of chloride and the extracellular chloride concentration, the assumption being made that all the chloride was extracellular in position. In *Cases* 16 and 17 an exception was made and the extracellular space was calculated from the tissue sodium content.

RESULTS

Normal Cases.—

1. *Water Content /kg. of Fat-free Muscle* (*Table I*).—In 13 muscle samples the average water content was 775·2 g. (Range 760·7–785·2, S.D. 6·6).

2. *Fat Content of Fresh Muscle* (*Table I*).—The fat content varied between 0·61 and 12·57 g./100 g. of fresh muscle.

3. *Composition/100 g. of Fat-free Tissue Solids* (*Table II*).—

Sodium 18·07 mEq. (Range 12·81–23·03, S.D. 2·56.)

Potassium 40·80 mEq. (Range 35·25–47·00, S.D. 3·20.)

Chloride 11·51 mEq. (Range 8·53–16·80, S.D. 2·28.)

Nitrogen 13·86 g. (Range 12·78–14·77, S.D. 0·58.)
Water 344·9 g. (Range 318·0–365·6, S.D. 13·2.)

5. *Composition /kg. of Fat-free Muscle* (*Table II*)
Sodium 40·63 mEq. (Range 28·70–53·08, S.D. 6·01.)

Table I.—WATER, SOLID, AND FAT CONTENT OF SAMPLES

No.	Site†	Weight of Sample	Operation or Diagnosis	G./1000 G. of Fat-free Muscle		G./224·8 G. of Fat-free Muscle		Fat Content: Percentage of Fresh Muscle
				Water	Solids	Water	Total	
		G.						
Normals.*—								
1	B	4·9381	Prostatectomy	785·2	214·8	821·7	1046·5	6·68
2	A	1·7997	Partial gastrectomy	783·7	216·3	814·3	1039·1	0·93
3	C	1·7570	Radical mastectomy	781·4	218·6	803·4	1028·2	4·05
4	A	1·7083	Cholecystectomy	781·2	218·8	802·4	1027·2	12·57
5	A‡	3·0683	Partial gastrectomy	778·5	221·5	790·0	1014·8	5·33
6	A	1·6529	Partial gastrectomy	776·5	223·5	780·9	1005·7	4·70
7	D	1·2104	Lumbar sympathectomy	776·1	223·9	779·3	1004·1	3·44
8	A	0·5503	Partial gastrectomy	771·8	228·2	760·2	985·0	2·51
9	E	2·9929	Partial nephrectomy	771·6	228·4	759·7	984·5	2·92
10	A	2·0517	Cholecystectomy	771·6	228·4	759·7	984·5	6·91
11	A	1·4399	Partial gastrectomy	770·5	229·5	754·6	979·4	3·12
12	A	0·6542	Partial gastrectomy	769·5	230·5	750·4	975·2	0·61
13	E	2·3060	Lumbar sympathectomy	760·7	239·3	717·6	941·4	2·59
			Mean	775·2	224·8	776·5	1001·3	—
			S.D.	6·6	6·6	27·2	27·2	—
Dehydrated.*—								
14	A	0·7719	Malnutrition, jaundice	762·2	237·8	720·4	945·2	11·61
15	A	2·4955	Pyloric stenosis	761·7	238·3	718·3	943·1	1·56
16	E	6·2717	Ureterosigmoidostomy	**755·0§**	**245·0**	**692·4**	**917·2**	1·42
17	E	3·0843	Subphrenic abscess	**754·5**	**245·5**	**690·7**	**915·5**	2·52
Overhydrated.—								
18	A	1·4111	Carcinoma of pancreas	**788·0**	**212·0**	**835·4**	**1060·2**	2·92
19	AB	3·3904	Enlarged prostate, cardiac failure	**788·0**	**212·0**	**835·4**	**1060·2**	2·97

* Arranged in order of decreasing water content.
† Sites: A, Rectus abdominis; B, Pyramidalis; C, Pectoralis major; D, Internal oblique; E, Others.
‡ Obtained from the same case as No. 6, but at the end of the operation.
§ In this and subsequent tables figures in bold type lie outside the ranges found in the normal series.

Table II.—TISSUE COMPOSITION

No.	Content/100 g. of Tissue Solids*						Content/1000 g. of Fat-free Muscle			
	H_2O	Na	K	Cl	N	K : N Ratio	Na	K	Cl	N
	g.	mEq.	mEq.	mEq.	g.		mEq.	mEq.	mEq.	g.
Normals.—										
1	365·6	18·48	41·26	12·77	14·21	2·90	39·68	88·59	27·40	30·55
2	362·0	17·70	41·00	12·00	14·00	2·93	38·32	88·76	22·61	31·00
3	357·0	17·72	45·90	11·95	12·97	3·54	38·78	107·6	25·97	28·39
4	357·0	17·25	40·26	11·40	14·18	2·84	37·75	88·00	24·96	31·00
6	348·0	21·60	47·00	13·95	14·02	3·35	48·21	104·9	31·14	31·29
7	346·5	12·81	40·13	8·62	12·78	3·13	28·70	89·86	19·31	28·64
8	338·3	—	36·71	16·80	—	—	—	83·71	38·32	—
9	338·2	19·26	39·11	11·61	13·90	2·82	43·94	89·25	26·50	31·72
10	337·8	16·16	42·18	9·81	13·88	3·04	36·93	96·34	22·41	31·62
11	336·1	17·63	35·25	9·02	14·77	2·39	40·50	80·90	20·70	33·85
12	333·6	23·03	41·96	11·64	—	—	53·08	96·72	26·82	—
13	318·0	17·14	38·84	8·53	—	—	41·00	93·00	20·40	—
Mean	344·9	18·07	40·80	11·51	13·86	2·99	40·63	92·30	25·56	30·90
S.D.	13·2	2·56	3·20	2·28	0·58	0·31	6·01	7·60	5·07	1·55
Dehydrated.—										
14	320·7	**26·26**	**28·36**	16·21	—	—	**62·43**	**67·42**	38·58	—
15	320·0	21·50	**33·40**	12·85	13·46	2·48	51·19	**79·52**	30·60	32·05
16	309·0	13·44	43·30	11·46	13·15	3·29	32·85	105·9	28·00	32·15
17	308·0	9·70	**34·40**	9·96	14·00	2·46	**23·81**	**84·43**	24·44	34·36
Overhydrated.—										
18	372·0	**24·40**	45·40	**17·75**	14·00	3·24	**51·70**	96·00	**37·60**	29·63
19	372·0	21·06	39·70	12·68	**11·65**	**3·41**	44·60	84·00	26·80	**24·70**

* For rationale *see* DARROW, HARRISON and TAFFEL (1939).

4. *K : N ratio* (*Table II*).—The average K : N ratio in the 9 cases in which the nitrogen was determined measured 2·99 (Range 2·39–3·54, S.D. 0·31).

Potassium 92·30 mEq. (Range 80·90–107·6, S.D. 7·60.)
Chloride 25·56 mEq. (Range 19·31–38·32, S.D. 5·07.)

Nitrogen 30·90 g. (Range 28·39–33·85, S.D. 1·55.)

6. *Tissue Fluid Distribution* (*Table III*).—

Extracellular fluid : 220·8 g./kg. of fat-free muscle. (Range 166·2–333·8, S.D. 45·2.)

Intracellular fluid : 554·2 g./kg. of fat-free muscle. (Range 438·0–609·9, S.D. 44·2.)

Intracellular phase : 779·2 g. of cells /kg. of fat-free muscle. (Range 666·2–832·8, S.D. 45·2.)

Intracellular water : 710·4 g. of water /kg. of cells. (Range 657·0–731·4, S.D. 18·9.)

In those cases in which it was reasonable to suppose that there existed some degree of dehydration the water content was low. *Case* 13, in the normal series, showed no clinical evidence of dehydration and is the only case which prevents the drawing of a sharp dividing line between normality and dehydration.

The ranges of normal tissue content of sodium, potassium, chloride, and nitrogen were fairly wide, and frequently the content of these substances in

Table III.—Derived Data

No.	Extracellular Fluid Concentrations			Water Distribution /1000 g. of Fat-free Muscle		Intracellular Phase/1000 g. of Fat-free Muscle	Intracellular Fluid/1000 g. of Cells	Intracellular Concentrations mEq./1000 g. of Intracellular Water		
	Na	K	Cl	E.c.	I.c.			Na	K	Cl
	mEq./l	mEq./l	mEq./l	g.	g.	g.	g.			
Normals.—										
1	157·1	4·99	116·0	236·2	549·0	763·8	718·8	4·7	159·2	0
2	152·2	5·60	106·3	212·7	571·0	787·3	725·1	10·4	153·3	0
3	156·5	4·48	112·0	231·9	549·5	768·1	716·9	4·5	193·9	0
4	159·9	4·17	116·9	213·5	567·7	786·5	721·8	6·4	153·4	0
6	156·5	4·59	115·8	268·9	507·6	731·1	694·2	12·1	204·2	0
7	158·0	5·55	116·2	166·2	609·9	833·8	731·4	4·0	145·8	0
8	159·5	5·15	114·8	333·8	438·0	666·2	657·0	—	187·2	0
9	158·9	4·49	116·2	228·0	543·6	772·0	704·2	14·2	162·3	0
10	163·3	4·40	117·2	191·3	580·3	808·7	717·4	9·8	164·6	0
11	158·8	5·21	118·9	174·1	596·4	825·9	721·9	21·6	134·2	0
12	155·8	5·73	119·1	225·2	544·3	774·8	702·6	33·1	175·3	0
13	163·0	5·50	122·0	167·2	593·5	832·8	712·9	23·2	155·2	0
			Mean	220·8	554·2	779·2	710·4	13·1	165·7	0
			S.D.	45·2	44·2	45·2	18·9	8·9	19·8	—
Dehydrated.—										
14	157·8	4·44	119·2	323·7	438·5	676·3	**648·5**	26·2	150·4	0
15	156·0	4·97	117·5	260·3	501·4	739·7	677·8	21·1	156·1	0
16	161·2	5·50	118·8	203·8*	551·2	795·8	692·8	0	190·0	**6·9**
17	155·0	4·20	109·6	**153·7***	600·8	**846·3**	709·9	0	**139·4**	**12·6**
Overhydrated.—										
18	153·5	3·95	112·9	333·2	454·8	666·8	682·2	1·3	208·6	0
19	138·6	5·23	100·5	266·7	521·3	733·3	710·8	14·6	158·5	0

* Determined by sodium content of the tissue.

7. *Intracellular Concentrations* (*Table III*).—

Sodium : 13·1 mEq./kg. of intracellular water. (Range 4·5–33·1, S.D. 8·9.)

Potassium : 165·7 mEq./kg. of intracellular water. (Range 145·8–204·2, S.D. 19·8.)

Abnormal Cases.—The results obtained in the six abnormal cases are presented in *Tables I–III*. The figures which fall outside the ranges found in the normal series are indicated by bold type. The number of cases studied is too small to merit any detailed presentation of the results in the individual cases.

DISCUSSION

The water content of fat-free muscle varied very little in the normal cases. In those cases clinically overhydrated (*Cases* 18 and 19) the water content was greater than the maximum water content found in the normal series. *Case* 18 had received intravenous therapy prior to operation and at operation the greater omentum and mesentery appeared somewhat œdematous. In *Case* 19, with low plasma-sodium and plasma-chloride concentrations (124·6 and 90·4 mEq./l. respectively) and early cardiac failure it was considered that there existed some disturbance of regulation of body fluid tonicity, with excess of water. the abnormal cases fell within the normal ranges. Similarly the K : N ratio in the abnormal cases was surprisingly constant, even in those cases (*Cases* 4, 17, and 18) with low plasma-potassium concentrations which normally suggest some measure of potassium deficiency. *Fig.* 85 shows the absence of correlation between the plasma-potassium concentration and the tissue K : N ratio, although it may be significant that in both cases with intracellular dehydration (*Cases* 14 and 15) the K : N ratio was low, while in *Case* 16, with extracellular dehydration, the K : N ratio was within the normal range.

The chloride ion has long been assumed to be wholly extracellular in position, although Deane, Ziff, and Smith (1952) have shown that between 19·8 and 40·4 per cent may be intracellular. Yannet and Darrow (1940) calculated the extracellular fluid volume from the extracellular chloride concentration and the (chloride–1) mEq./100 g. of fat-free tissue solids, since Manery, Danielson, and Hastings (1938) showed that some chloride is probably associated with collagen rather than with the ultrafiltrate of serum. The high values found for extracellular fluid volume in two of the normal cases (*Cases* 6 and 8) may possibly have their explanation in this observation of Manery and others. In two of the

abnormal cases (*Cases* 16 and 17) some chloride must have been intracellular, the volume of the extracellular phase being determined by the amount of sodium present. Gastro-intestinal aspiration in

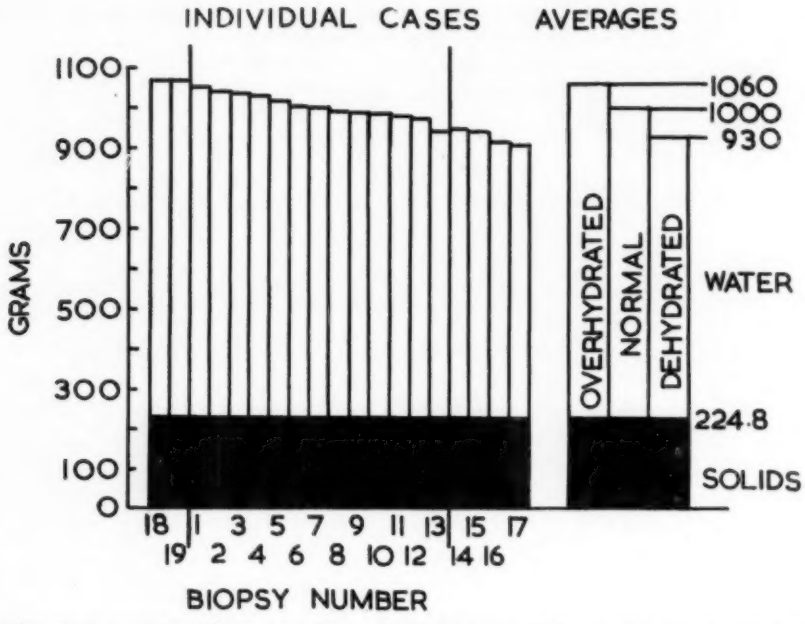

FIG. 84.—Showing water content of tissue related to a constant amount of tissue solids (224·8 g., being the average solid content of 1000 g. of fat-free muscle in the normal cases). The individual results have been arranged arbitrarily in order of decreasing water content in each of the three groups, overhydrated, normal, and dehydrated.

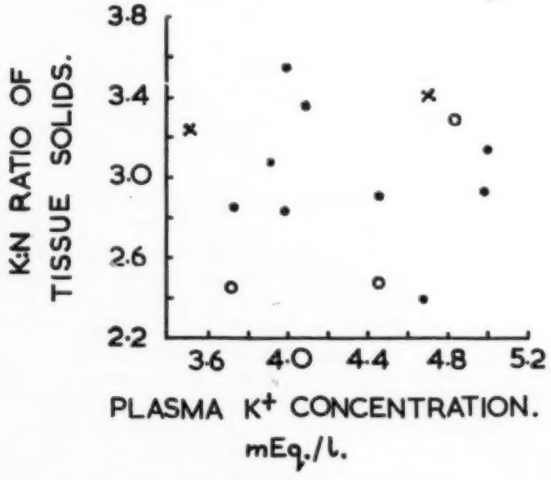

FIG. 85.—Showing absence of correlation between the plasma-potassium concentration and the tissue K : N ratio. (Normal cases are shown by •, dehydrated cases by o, and overhydrated cases by x.)

Case 17 may have led to a greater loss of sodium than of chloride, with the development of a relative sodium deficiency, while the state of hyperchloræmia in *Case* 16 may, in fact, represent a state of true sodium deficiency (Wilson, 1953).

In general the water content of the cells remained remarkably constant, and in only 1 case (*Case* 14) was it found to be much reduced. (*Fig.* 84.)

Although by the method of tissue analysis a considerable amount of information may be gained about the fluid and electrolyte distribution in muscle, there are several factors which must influence the clinical application of this method of investigation. The considerable range of normal values makes more difficult the assessment of the significance of results obtained in unbalanced cases. No single result can be expected to provide an answer to the problem of the nature of the extent of any imbalance except perhaps the water content/unit weight of fat-free tissue which is a measure of the state of hydration, without reference to whether this is intra- or extracellular.

If a somewhat elaborate method of investigation of the state of fluid and electrolyte metabolism is to be of clinical value it should ideally be applicable to as many patients as possible. This desideratum may be achieved if the muscle samples are obtained under local anæsthesia, although there are two disadvantages if a local anæsthetic is employed: First, there may be contamination of the muscle sample by the local anæsthetic, and secondly, if the anæsthesia is limited to skin and superficial tissues, the actual process of sampling the muscle may be rather painful (Mokotoff and others, 1952). Biopsies can best be obtained under general anæsthesia, and if the results were likely to be of sufficient value to influence the treatment of a seriously ill patient then this would be the method of choice.

For the results to be of significance the biopsy must be taken early in the course of the operation. As shown by Winfield and others (1951), there is during the course of the operation a considerable decrease in the potassium content and a considerable increase in the sodium content of muscle obtained at the site of operation. The muscle sampled should be as free as possible from fat, and more particularly from fibrous tissue on account of the high chloride content of fibrous tissue.

SUMMARY

Muscle samples were obtained from 12 normal cases, from 2 cases clinically overhydrated, and from 4 cases clinically dehydrated.

Tissue water, fat, solids, sodium, potassium, chloride, and nitrogen were determined.

Normal muscle water content showed little variation, and the contents of potassium and nitrogen were relatively constant.

Tissue sodium and chloride contents showed more variation in the normal cases.

Factors are discussed which may influence the clinical application of this method of investigation.

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THE BLOOD-SUPPLY OF THE COMMON BILE-DUCT AND ITS RELATIONSHIP TO DUODENUM

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AT the Middlesex Hospital, in the surgery of the biliary tract or duodenum, it was noted that the common bile-duct received numerous small vessels, particularly in the supraduodenal portion, and that there appeared to be a constant artery which passed in front of the supraduodenal portion of the duct from left to right. At the suggestion of Mr. R. Vaughan Hudson, investigation was made into the origin of this artery. In common with other authors, it was found that the standard text-books of anatomy contained little reference to the blood-supply of the common bile-duct. It was therefore decided to use the cadaver, and, by means of radio-opaque fluid injected into the arterial trunks, investigation into the blood-supply of the common bile-duct and the duodenum was carried out.

HISTORICAL

Wilkie (1911) dissected 40 cadavers to ascertain the blood-supply of the duodenum, and in his paper he described in detail the supraduodenal artery which supplies the anterior and posterior upper two-thirds of the first part of the duodenum. He then went on to state : " In the majority of cases a second artery was found, springing from the gastroduodenal artery about ½ in. above its bifurcation and supplying the posterior wall of the first part of the duodenum and sometimes reaching to the second part. This vessel, though not constant, was generally present and I have ventured to name it the retroduodenal artery."

This description is the first in the literature of this particular artery, and henceforth I will refer to it as the retroduodenal artery of Wilkie.

Flint (1923), in a study of the abnormality of vessels and ducts of the liver in 200 post-mortems, stated that in opening the common duct " it is quite common to have an annoying hæmorrhage from an artery which crosses the front of the supraduodenal path of this duct. Though a plexus of veins and arterioles are described on the surface of the duct, I have seen no mention of this artery in the literature. Surgeons know it well, and I was curious therefore to discover its source. I am unable to give the frequency of its existence as I did not begin to look for it from the first, but I found it quite often ; it arises from the hepatic artery low down, or from the superior pancreatico-duodenal, or from the gastro-duodenal, and runs a rather tortuous course along the anterior surface of the duct ".

Kellogg (1933) stated that the gastroduodenal artery gave off a retroduodenal branch before dividing into its two terminal branches, and claimed that this artery supplied the lower two-thirds of the posterior surface of the duodenum.

Wilmer (1941) briefly described the blood-supply of the pancreas and the duodenum, with emphasis upon the gastroduodenal plexus ; an anastomosis between the gastroduodenal and the superior mesenteric arteries lying behind the duodenum. There was no mention of the common bile-duct or of its blood-supply.

THE BLOOD-SUPPLY OF THE COMMON BILE-DUCT

The most comprehensive reference to the blood-supply of the common bile-duct was made by Linden Edwards in 1941. In his brief article he stated that text-books do not describe a conspicuous branch of the gastroduodenal artery, so with his students he investigated 100 cadavers. This they did pains-takingly, adhering to Wilkie's nomenclature, calling

it the retroduodenal artery. He stated that the gastroduodenal artery originated from the common hepatic artery and divided at the lower border of the first part of the duodenum into right gastro-epiploic and superior pancreatico-duodenal arteries. It lay anterior to the portal vein and slightly to the left of the common bile-duct. Grant pointed out that it gave off an end-artery, the supraduodenal artery of Wilkie, but according to Wilkie (1911) the

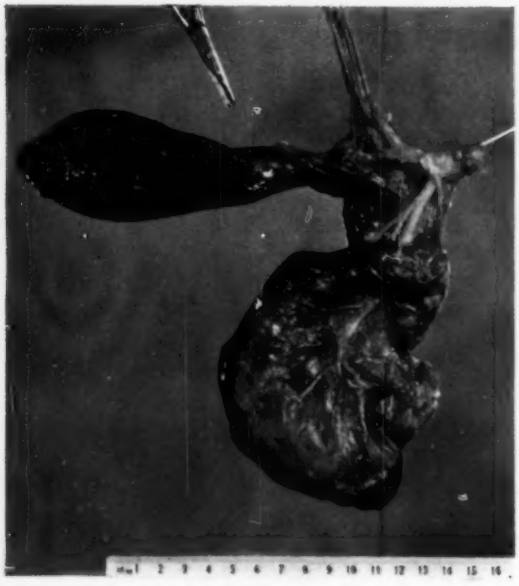

FIG. 86. – Coloured picture of a dissection showing the retroduodenal artery of Wilkie leaving the gastroduodenal artery and disappearing behind the duodenum.

supraduodenal artery arises most commonly from the gastroduodenal, and less commonly from the right and left hepatics, the common hepatic, the cystic, and the retroduodenal arteries.

Edwards identified the intact artery in 97 per cent of the 100 cadavers. In 2 it may have been destroyed by dissection, and in the remaining 1 was replaced by numerous small vessels. In 94 per cent of the bodies in which it was present, it originated from the gastroduodenal artery. In 4 the gastro-duodenal and the retroduodenal arteries arose as a common trunk from the common hepatic artery, and in 3 it originated from an accessory hepatic artery which came from the superior mesenteric artery. It never arose from the normal common hepatic or superior pancreatico-duodenal arteries. Commonly it began about 1·5 cm. from the point of origin of the gastroduodenal artery, passed to the right posterior to the first part of the duodenum to the superior duodenal angle, at which point it descended following the curvature of the descending portion of the duodenum, in the interval between the duodenum and the pancreas, to about the level of the inferior angle, where it curved to the left and passed to the posterior surface of the pancreas. In the majority of bodies it anastomosed with a branch of the inferior pancreatico-duodenal artery.

Poirier and Charpy (1901), Reeves (1920), Kellogg (1933), and Grant (1940) all described an anterior and posterior arcade which extended along the concavity of the duodenum and which was formed by branches of the superior and the inferior pancreatico-duodenal arteries. In Edwards's series the anterior arcade was formed by the anastomosis of the superior pancreatico-duodenal artery, whilst the posterior arch was formed in 80 per cent of the bodies by the anastomosis of the retroduodenal artery with a posterior branch of the inferior pancreatico-duodenal artery. In the other 20 per

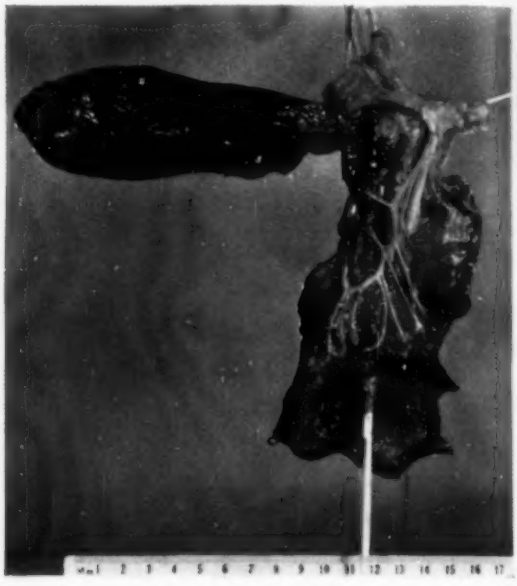

FIG. 87.—In this picture the duodenum is turned forwards to show the retroduodenal artery from the posterior aspect. The glass rod is in the common bile-duct, entering at the ampulla of Vater. It will be seen that the artery anastomoses with the posterior branch of the inferior pancreatico-duodenal artery, and before it reaches this level it gives off branches to the common bile-duct. It also gives off vasa recti which run a straight course, supplying the duodenum on its posterior aspect.

cent the retroduodenal artery terminated by breaking into minute branches. Edwards then stated that in all cases the retroduodenal artery was in intimate relationship with the pancreatic portion of the common bile-duct.

Shapiro and Robillard, of Brooklyn (1946), discussed in detail the blood-supply of the duodenum and its relationship to the gastrectomy duodenal stump, bleeding peptic ulcer, and injury to the common bile-duct. They described the various causes for a duodenal leak following the Polya gastrectomy. They also studied dissections in 62 bodies and gave the following figures. The supra-duodenal artery of Wilkie arose in 60 per cent from the gastroduodenal artery, and in 15 per cent from the common right or left hepatic artery, 12 per cent from the right gastric, 6 per cent from the superior pancreatico-duodenal artery, 3 per cent from the cystic artery, and 3 per cent from the hepato-gastroduodenal anastomoses. The supraduodenal artery is the main blood-supply of the first part of the duodenum. The second and third parts of the duodenum receive their blood-supply essentially from the anterior and posterior pancreatico-duodenal arcades. These arcades are an anastomosis between the cœliac axis and the superior mesenteric axis and

may lie on the pancreatic head or in the groove between the pancreatic head and the duodenum. The arcades may run a tortuous course, but the vasa recta running from the arch to the duodenum maintain a reasonably straight course and therefore any attempt to separate the pancreas from the duodenum must be attended by the ligation of the vasa recta. In 14 per cent of their bodies the inferior pancreatico-duodenal artery was less constant than the superior pancreatico-duodenal artery. In these 14 per cent it did not anastomose with the superior pancreatico-duodenal artery, but faded into minute twigs going to the head of the pancreas and the third part of the duodenum.

These authors disagreed with Wilmer (1941), who found a large gastroduodenal plexus of relatively large vessels in addition to the above arcades which originated from the gastroduodenal artery and the superior mesenteric artery and was situated posterior to the duodenum. These same authors then described the posterior superior pancreatico-duodenal artery as follows: "It originates from the

FIG. 88.—Demonstrates the filling of the arterial tree and the emergence of the retroduodenal artery of Wilkie about 1 in. below the origin of the gastroduodenal artery.

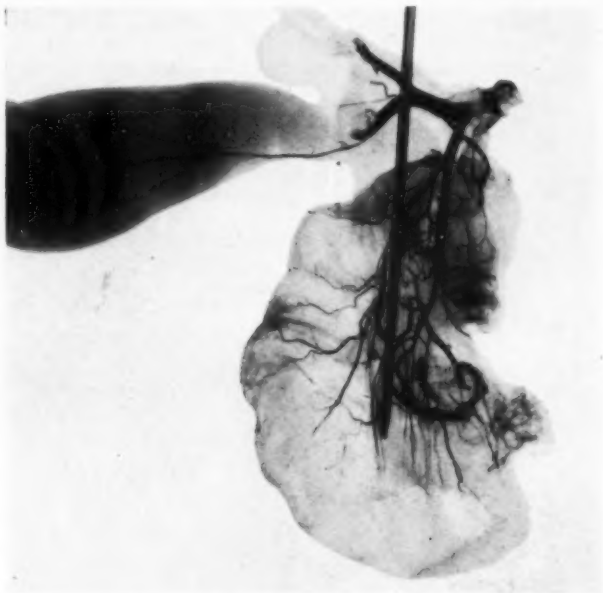

FIG. 89.—Demonstrates the anteroposterior view of specimen, with glass rod in common bile-duct.

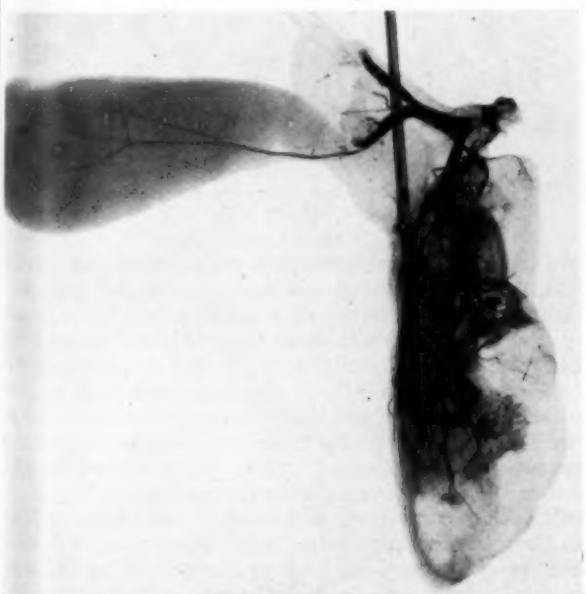

FIG. 90.—Shows the lateral view with glass rod in position.

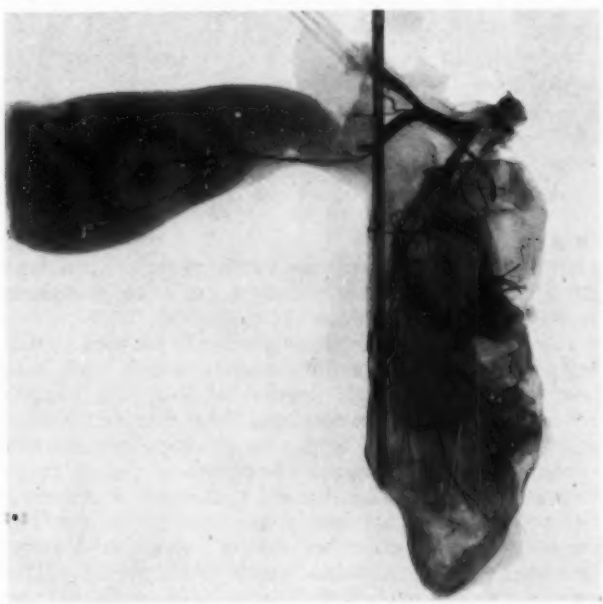

FIG. 91.—Demonstrates the vascular tree around common bile-duct when the rod is displaced lateralwards under tension.

right dorsal side of the gastroduodenal artery and as it descends it crosses anteriorly in 75 per cent to the right of the retroduodenal common bile-duct, curves around it, and, crossing it dorsal to the intra-pancreatic portion, descends towards the left, thus usually forming an arterial hook around the duct contributing to it several small branches. One or more of these twigs extends along the

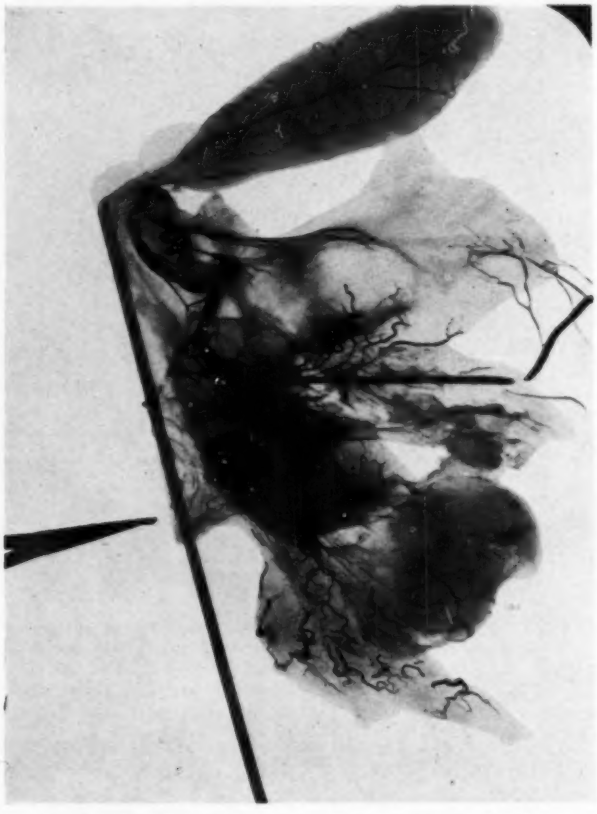

FIG. 92.—Reveals the vascular supply of the common bile-duct after the adventitia has been dissected away.

common duct. Injury to these vessels may lead to localized ischæmic necrosis of the common bile-duct."

A further paragraph is devoted to the blood-supply of the common bile-duct in which they state that the retroduodenal portion of the duct usually receives three to five twigs from the posterior superior pancreatico-duodenal artery as it loops around the common duct. Except in one or two instances, these vessels enter the wall of the duct after a short external course. The remaining twigs ascend along the medial border or to either side of the duct, in some instances ending as an accessory cystic artery. The supraduodenal artery also gave a branch to the common bile-duct in 2 instances. The right hepatic artery gave several small branches to the central and upper sections of the duct, and the gastro-duodenal artery contributed to the lower third of the duct. Further, the cystic artery also gave twigs to the upper part of the duct.

Method of Investigation.—The left gastric artery and the superior mesenteric artery were ligated at their origins. The right and left hepatic arteries were also ligated and a clamp was placed across the antrum of the stomach to prevent loss of radio-opaque material into the right gastric and right gastro-epiploic vessels. The common hepatic artery was then dissected free and a cannula was inserted to fit a 50-c.c. syringe loaded with a saturated suspension of bismuth carbonate. A ligature was placed around the vessel to hold the cannula in place and prevent leakage. The bismuth carbonate was slowly perfused through the arterial tree and its progress could be readily seen as the vessels became white and distended. The tension on the plunger

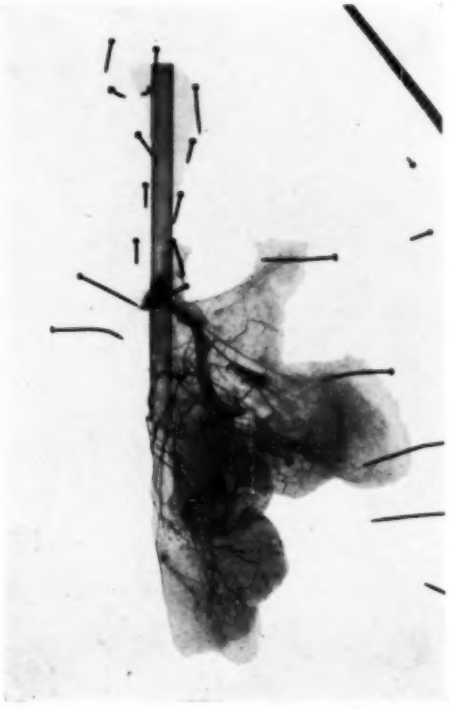

FIG. 93.—Clearly demonstrates the vascular pattern around the duct

indicated when the arterial arcades were reasonably full, at which point the cannula was withdrawn and the ligature tied tightly to prevent reflux. A dissection was then carried out to remove from the body in one piece the following organs: the duodenum, the head and isthmus of the pancreas, the pyloric part of the stomach, the biliary apparatus consisting of right and left hepatic ducts and the common bile-duct, together with the cystic duct and gall-bladder (*Fig.* 86). All vessels were severed proximal or distal to the point of ligation to prevent any spill of the radio-opaque material. This specimen was then transfixed to a thin board of non-radio-opaque material, and X-ray photographs were taken in the anteroposterior plane and in the lateral plane. A long thin glass tube, almost 0·5 cm. diameter, filled with radio-opaque material and with one end sealed off in a flame, was then passed down the common bile-duct until it protruded into the duodenum through the ampulla of Vater. A further radiograph was then taken in the anteroposterior and one in the lateral plane. The common bile-duct with its vessels was then further dissected from the adventitia surrounding

the duct and the constant retroduodenal artery of Wilkie was dissected along its course, and a colour photograph taken (*Fig.* 87).

RESULTS

The X-ray photographs demonstrate the presence of this retroduodenal artery arising from the gastroduodenal artery about ½–1 in. below its origin. Leaving the gastroduodenal artery, behind the first part of the duodenum it passes to the right for about 1 in., then curves anteriorly in front of the retroduodenal part of the common bile-duct, at which level it gives off one twig which passes upwards to supply the duct. The main artery travels downwards on the right (or lateral side) of the common bile-duct, supplying arterioles to it along its whole course, with terminal twigs at the ampulla of Vater. In most instances there is a good anastomosis between this artery and the posterior branch of the inferior pancreatico-duodenal artery which originates from the superior mesenteric artery.

Fig. 88 demonstrates the filling of the arterial tree and the emergence of the retroduodenal artery of Wilkie about 1 in. below the origin of the gastroduodenal artery. The duodenum is turned forwards in this instance to show the lateral course of the artery and it should be noted that the terminal twigs become very fine at approximately the junction of the second and third portions of the duodenum on the inner aspect of the pancreatico-duodenal curve. In *Figs.* 89–91 it will be seen that these terminal twigs end at the ampulla of Vater.

Fig. 89 demonstrates the anteroposterior view of the specimen, with the glass rod in the common bile-duct. Again the artery can clearly be seen in its course.

Fig. 90 shows the lateral view with the glass rod in position.

Fig. 91 demonstrates the vascular tree around the common bile-duct when the rod is displaced lateralwards under tension, as shown by the bulge in the shadow of the duodenum.

Fig. 92 reveals the vascular supply of the common bile-duct after the adventitia has been dissected away. The ampulla of Vater is demarcated by the pointer. It will be noted that as soon as tension is put on the glass rod the vessels will tend to empty at the points of contact, hence allowance must be made for the altered appearance.

Fig. 93 clearly demonstrates the vascular pattern around the duct.

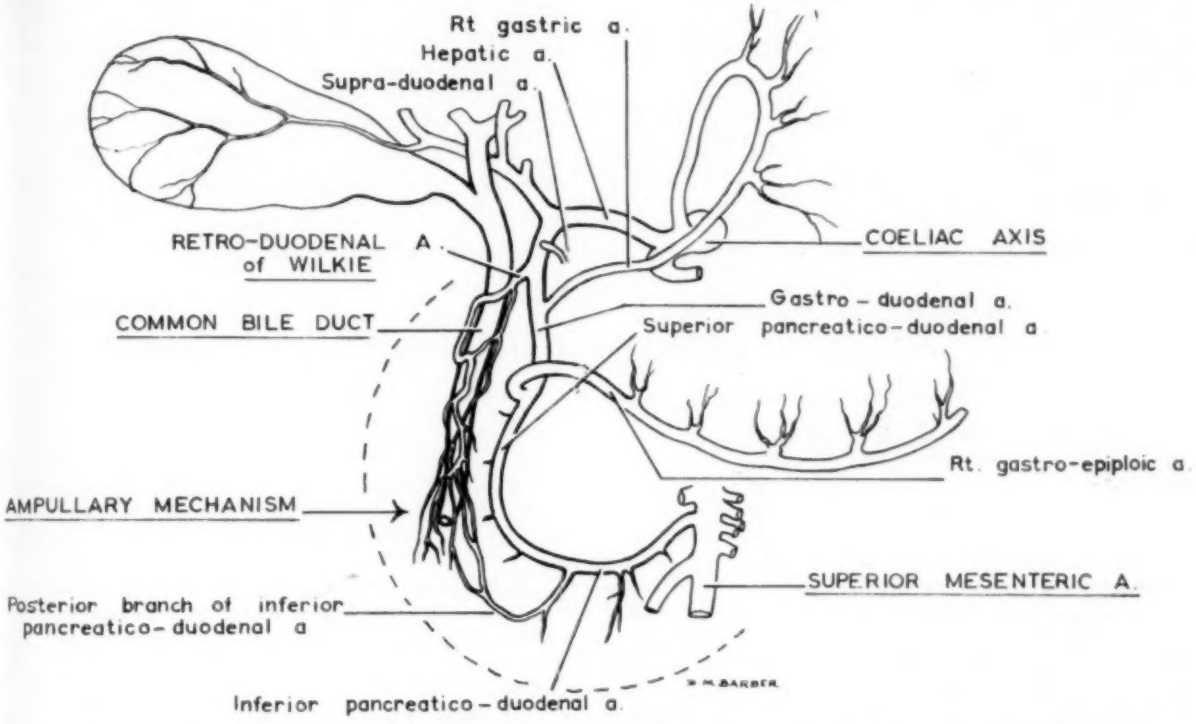

FIG. 94.—Composite drawing taken from numerous radiographs to demonstrate the arterial supply to the common bile-duct and the ampullary mechanism.

This investigation was carried out on 12 cadavers and revealed a fairly constant pattern. In 2 cases there appeared to be a poor anastomosis between the termination of the retroduodenal artery of Wilkie and the posterior branch of the inferior pancreaticoduodenal artery. In 1 instance the main hepatic artery originated from the superior mesenteric artery and travelled anteriorly to reach the porta hepatis.

CONCLUSION

It would appear from the study of the literature, and confirmed by this investigation, that the common bile-duct receives its blood essentially from one artery, which was first described by Wilkie in 1911. It is called the retroduodenal artery of Wilkie, originates from the gastroduodenal artery, and ends

by anastomosing in most instances with the posterior branch of the inferior pancreaticoduodenal.

A knowledge of this vessel is important surgically, for where it does not anastomose freely with the inferior pancreatico-duodenal, ligation of the vessel proximally might result in gangrene of the terminal part of the duct and a biliary fistula, or may be responsible for the occurrence of a common bile-duct stricture, some weeks or months after apparently uncomplicated surgery.

Appreciation.—This work was carried out in the Bland-Sutton Institute of Pathology, the Middlesex Hospital, and I am indebted to Professor R. Scarff for the privilege.

It was completed at the Research and Educational Hospital, Chicago, and the University of Illinois, and sponsored by Dr. Warren H. Cole, M.D., Head of the Department of Surgery, during the tenure of a Smith-Mundt Travelling Fellowship.

The photography is the work of Mr. A. G. Booker, of the Central Middlesex Hospital, and the colour reproductions were made by Mr. Turney, of the Photographic Department of the Middlesex Hospital. *Fig.* 94 is the beautiful work of Miss D. M. Barber.

The ever-willing co-operation of Professor E. W. Walls, Courtauld Professor of Anatomy, Middlesex Hospital Medical School, is much appreciated.

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METASTASIZING CARCINOMA OF THE SWEAT-GLANDS

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SINCE 1865, when the first case of sweat-gland carcinoma was recorded (Cornil), a number of cases have been reported, but in the majority the diagnosis of malignancy has been based on the histological appearance, and in only the minority has clinical evidence of malignancy been described.

In 1943 Gates, Warren, and Warvi reviewed the subject and collected 29 cases from the literature, adding 6 cases of their own. In only four of these 35 cases were metastases reported; there was evidence of local recurrence after excision in 4 others. More recently Duany (1950) has produced a comprehensive survey of sweat-gland tumours, collecting 64 cases of sweat-gland epitheliomas from world literature. Some of these are almost certainly benign tumours, for example Cases 46, 47, and 50, and this collection produces only an additional four metastasizing cases.

Many other cases of sweat-gland carcinoma have been described, but they are either of doubtful malignancy (Lever, 1947) or of doubtful sweat-gland origin (Schreiner and Wehr, 1934; Lacey, 1946; Arnold, 1948). McDonald, Loveday, and Waugh (1941) describe 32 cases of adenocarcinoma of vulva, but 30 of these were clinically benign and pathologically resembled simple hydradenoma, the other two were malignant but there was no proof of sweat-gland origin.

In other cases malignancy is based entirely on the histological picture. Lennox, Pearse, and Richards (1952) describe a case of low-grade mucoid carcinoma of sweat-gland, occurring on the scalp and pathologically resembling a breast carcinoma; clinically this was a benign, encapsulated tumour of six years' slow growth, which did not recur after excision.

Reports of cases of undoubted sweat-gland origin, and showing *clinical* evidence of malignancy (invasion of surrounding structures, recurrence after local excision, and especially metastases) are few and far between. There appear to be no reports of such cases in British literature. All authorities agree that metastasizing sweat-gland carcinoma is very rare.

Lee, Pack, and Scharnagel (1933) collected 81 patients with so-called sweat-gland carcinoma of breast, 32 of whom had axillary metastases. They describe the histological basis for differentiating these tumours from true breast cancer, but most authorities do not recognize sweat-gland carcinoma of breast as a separate entity (Dawson, 1932; Gates and others, 1943), and in view of the frequency of metastasis in true breast cancer and its rarity in sweat-gland tumours in other sites, it is more likely that the so-called sweat-gland carcinoma of the breast is in reality a variety of breast cancer.

Benjamin (1947) describes a case of tumour of the ear with multiple skin metastases; it is not certain that these multiple skin tumours, which varied microscopically, all arose from a single primary lesion : they may well have been multifocal in origin.

Stout and Cooley (1951) collected 13 cases of metastasizing sweat-gland carcinoma including 6 of their own. Their sixth case is excluded as quite possibly originating in breast tissue. The remaining cases are set out in *Table I*, together with 8 other cases from the literature, forming what is believed to be a complete list of recorded cases of indisputable metastasizing sweat-gland carcinoma. One new case (Tanner's case) is reported in some detail on account of the rarity of the condition and features of special interest.

CASE HISTORY

January, 1951 : A healthy man, aged 40, attended St. James' Hospital under Mr. N. C. Tanner with a small firm swelling in centre of forehead. He stated

that a similar swelling had been removed some two and a half years previously and had recurred about six months later. (Pathological report on original tumour not available.)

The lump was excised with ¼ in. skin margin. The wide gap was sutured with use of a relieving incision.

adenoma in which some glands were apparently secreting a mucoid substance. (2) A solid area with hyaline change in the stroma. Conclusion: Sweat-gland adenoma.

May, 1953: Attended with five swellings on forehead fixed to skin, not to bone (*Fig.* 95).

Table I.—RECORDED CASES OF METASTASIZING SWEAT-GLAND CARCINOMA

CASE NO.	AUTHOR	SEX	AGE	SITE OF PRIMARY	GLANDULAR METASTASES	DURATION	PATHOLOGY	REMARKS
1	Kreibich (1907)	M.	71	Scalp	Cervical	—	Adenocarcinoma	Died
2	Hedinger (1911)	F.	48	Scalp	Cervical	About 35 years	Adenocarcinoma	Excised with local excision of lymph-nodes. No follow-up
3	Sekiguchi (1917)	M.	65	Scrotum	Inguinal	2 years	Adenocarcinoma with Paget cells	Excised with glands. No follow-up
4	Morini and Montagnani (1921)	M.	33	Scalp	Regional	—	Epithelioma	Also abdominal metastases
5	Calissano (1926)	M.	63	Groin	Inguinal	3 months	Adenocarcinoma	Excised. No follow-up
6	Hufschmitt and Diss (1929)	F.	61	Scalp	Regional	37 years	Adenocarcinoma	Excised; recurred in 6 months with metastases
7	Crosti (1931)	F.	61	Occipital	Parotid	—	Adeno-epithelioma	Died in 5 months
8	Moriconi (1931)	M.	59	Axilla	Regional	6 months	Carcinoma	Radical axillary dissection. Well 5 years later
9	Eichenberg (1934)	F.	30	Vulva	Inguinal	3 years	Adenocarcinoma	Excised with glands. Well 2 years later
10	Weiner (1937)	F.	84	Vulva	Regional	7 years	Adenocarcinoma with Paget cells	Widespread metastases. Died in 6 months
11	Suzuki (1941)	—	—	Knee	Inguinal	—	'Medullary' carcinoma	No record
12	Horn (1944)	M.	31	Wrist	Axillary	15 years	Papillary adeno-carcinoma	Excised four times, also radiotherapy. Finally amputation and axillary dissection. Well three months later
13	Maier (1949)	M.	58	Thigh	Inguinal	25 years	Papillary adeno-carcinoma	Excised. Died six months later with peritoneal metastases
14	Zink (1950)	M.	27	Ear	Cervical	2½ years	Adenocarcinoma	Radiotherapy with recurrence. Excised with glands. No follow-up
15	Stout and Cooley (1951)	M.	59	Arm	Axillary	18 years	Adenocarcinoma	Excised with recurrence. Radio-therapy. Died 37 months after excision, with lung metastases
16	Stout and Cooley (1951)	F.	36	Axilla	Axillary	2½ years	Adenocarcinoma with epithelial strands	Radiotherapy; later radical excision with axillary glands. Recurred and re-excised. Died 27 months after first operation, with vertebral metastases
17	Stout and Cooley (1951)	F.	44	Inner canthus	— —	2 months	Papillary adeno-carcinoma	Excised; microscopically benign. Recurred and re-excised three times. Radiotherapy given. Died 22 months after first operation, with lung metastases
18	Stout and Cooley (1951)	F.	48	Axilla	Axillary	1 year	Papillary adeno-carcinoma	Excised. Later radical axillary dissection but recurrence in 1½ months
19	Stout and Cooley (1951)	M.	49	Arm	Axillary and cervical	23 years	Papillary adeno-carcinoma	Excised twice, then radiotherapy. No further follow-up
20	Neely (1952)	F.	62	Arm	Axillary	—	Adenoma	Excised and radiotherapy given. No follow-up
21	Tanner's case (1955)	M.	40	Scalp	Cervical	2½ years	Papillary adeno-carcinoma	Excised four times. Later block dissection of neck, probable local recurrence 22 months later.

The tumour was not attached to the pericranium, and did not appear to be encapsulated. It was of solid fleshy consistency.

Microscopical report: Invasive sweat-gland adenoma.

June, 1952: Attended with seven further lumps on forehead in region of hairline. Three of these were removed. They were encapsulated and contained a brownish semi-solid material.

Microscopical report: Sweat-gland adenoma with two distinct histological structures: (1) A papillary

Wide excision of area of scalp containing the swellings was performed (*Fig.* 96), in continuity with the right parotid lymph-gland. Thiersch graft was applied and, healing was satisfactory (*Fig.* 97).

Microscopical report: Sweat-gland adenocarcinoma invading surrounding tissue (*Fig.* 98). Frozen section of lymph-gland showed sweat-gland tumour replacing normal architecture of gland.

July, 1953: Hard palpable gland below right auricle, and a soft mass below angle of jaw.

Excision of right parotid gland and block dissection of right side of neck carried out by Mr. N. C. Tanner.

Microscopical report: Cervical glands showed sweat-gland adenocarcinoma (*Figs.* 99, 100). Parotid gland showed no metastases.

FIG. 95.—Photograph of forehead, September, 1952. Two of the tumours are clearly seen. Note scars of previous operations.

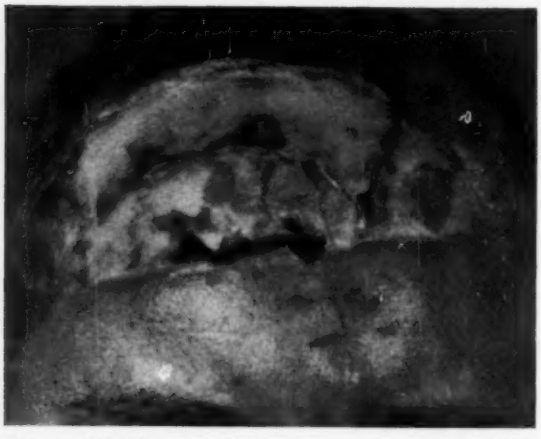


FIG. 97.—Specimen showing the area of scalp containing tumours which was excised.

April, 1955: Well. No sign of recurrence.

May, 1955: Two small firm swellings present in skin above right clavicle, suggestive of recurrence. Further radical surgery is contemplated.

PATHOLOGY

The basal-cell elements of the skin, which include the dermal glands, give rise to certain tumours, the classification and differentiation of which has caused much confusion. These tumours may be epidermal in origin or may arise from hair follicles, sebaceous, apocrine, or sweat-glands. In many cases the exact origin may be difficult or impossible to determine. Much depends on the histological interpretation. Often elements of more than one subepidermal structure are present. Sometimes a tumour may show evidence of both squamous- and basal-cell origin (Gates and others, 1943, Case 40–2059).

For these reasons the classification of tumours arising from sweat-glands has always been somewhat confused. This confusion has not only arisen in differentiating between an origin from sweat-gland or other basal-cell element, but also in deciding whether the tumour is truly malignant. The relation of sweat-gland tumours to Paget's disease (Lubschitz, 1944; Setala, 1949; *Cases* 3 and 10 in *Table I*), to melano-epithelioma (Duany, 1950), to mixed salivary tumours (Lennox and others,

FIG. 96.—Scalp showing area covered with Thiersch grafts five weeks after operation.

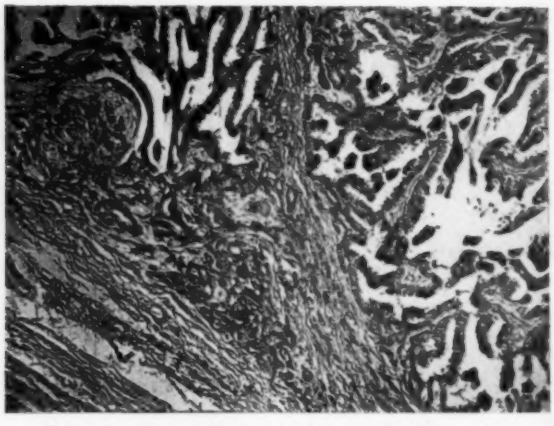


FIG. 98.—Sweat-gland carcinoma. Sections show a papillary adenocarcinoma invading the deeper dermis and subcutaneous tissues. The epithelium is frequently heaped up; many mitoses are present. Mucoid change is a prominent feature.

1952), and to mammary gland cancer is also controversial. Primary hypertrophy and hyperplasia of sweat-glands are rare, though these changes may occur in association with some angiomas and nævi, and confusion with true sweat-gland tumours may arise.

Though many borderline and mixed types occur, certain recognized pathological forms of sweat-gland tumours are described. The classification of Gates and others seem simple and satisfactory:—

1. *Syringoma*, showing columns of epithelial cells with cystic spaces scattered through the corium.

2. *Hydradenoma Papilliferum*, with predominantly papilliferous structure often resembling a carcinoma. Many of the tumours described as adenocarcinoma of the vulva probably belong to this group, being in reality simple tumours.

3. *Hydradenoma* (cylindroma), showing solid cell masses with alveolar spaces.

4. *Hydradenoid Carcinoma* (malignant), usually a solid tumour. It may occur as a malignant change in a hydradenoma; differentiation between benign and malignant is often difficult.

Gates and others do not differentiate between tumours arising from the secretory and the ductal parts of the sweat-gland; they differentiate larger-celled apocrine-gland tumours from tumours of the true (eccrine) sweat-glands and consider that the former are not uncommon, but never become clinically malignant, whereas Willis (1948) considers that sweat-gland and apocrine-gland tumours form a single group.

Sweat-gland tumours may contain myo-epithelial cells, and at times the myo-epithelial element predominates (Grynfeltt and Aimes, 1922—Case 2; Sheldon, 1941—Case 3; Hartz, 1946).

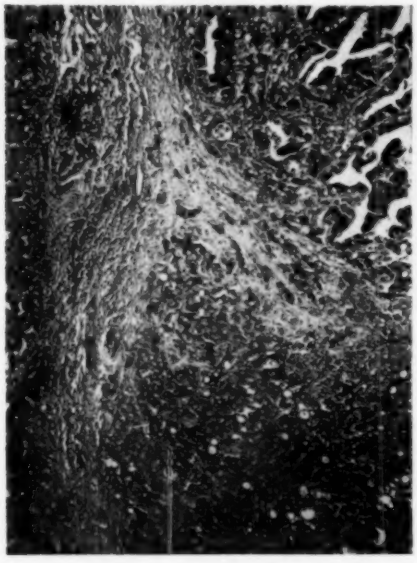
Some tumours, probably originating from the ductal portion of the gland (Duany, 1950), may contain squamous-cell elements; they have been called adenocanthomas by Lever, and sweat-gland epitheliomas by Stout and Cooley (1951).

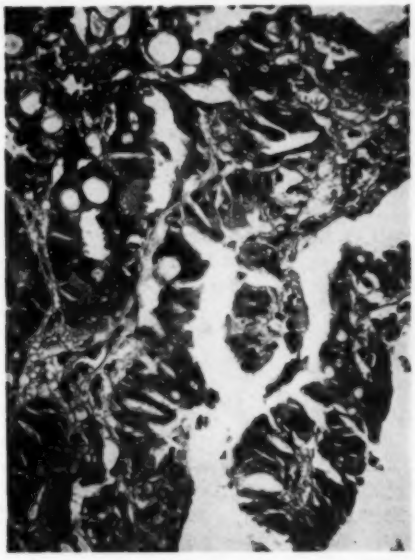
Duany sharply distinguishes the clinically benign sweat-gland epithelioma which resembles a basal-cell carcinoma from the rare anaplastic adenocarcinoma which metastasizes to lymphatic glands and resembles adenocarcinoma of breast or stomach.

Lever (1948) believes that these tumours of so-called basal-cell origin are derived from incompletely differentiated embryonic cells; they are nævoid tumours and any stage of development may be seen in a growth. They may be undifferentiated (such as a rodent carcinoma) or show differentiation towards dermal gland structure. These tumours, forming the great majority of basal and subepithelial neoplasms, he considers are not truly malignant and never metastasize. He allows, however, that a true carcinoma capable of metastasis may occur, forming a separate group of different origin; it arises from anaplastic, de-differentiated cells of the dermal glands.

Malignant tumours of sweat-glands range from those with a well-differentiated papillary structure, resembling and possibly arising from hydradenoma papilliferum, to a solid carcinoma sometimes with so little acinar structure as almost to resemble a basal-cell carcinoma in appearance.

The former papillary type may appear microscopically malignant, but is almost always clinically benign. Its true origin from sweat-gland is usually clear, but its malignancy is often disputable.





FIGS. 99, 100.—Sections of cervical lymph-gland. The normal architecture of the lymph-node is replaced by metastatic carcinoma similar to the primary tumour but more anaplastic.

At the other end of the scale controversy exists as to the exact origin of the more cellular growth, and it is, in fact, often impossible to decide from which of the subepidermal structures it has originated. The more undifferentiated of these tumours may so closely resemble a basal-cell carcinoma as to be indistinguishable, but even though a tumour of this type shows undoubted evidence of sweat-gland origin, it often behaves clinically as a basal-cell cancer as regards local invasion of tissue and a tendency to recur after local excision, but with no tendency to metastasize. Tumours of this type are described by Morisani, cited by Loos; Thierfelder (1870); Diss and Peterschmidt (1926); Gates and others, 5 cases (1943); Lubschitz (1944); Stout and Cooley, 5 cases (1951) and Kaplan (1952).

The rare *metastasizing* sweat-gland carcinomas form a distinct group. They are mostly adeno-carcinomas with marked acinar structure. Metastases rarely, if ever, occur from the more common solid basal-cell type, or from the myo-epithelioma or the adeno-acanthoma. The metastasizing tumours may run a clinically benign course for many years, and may in their early stages appear microscopically as benign adenomas (*Cases* 14, 20, and 21 in *Table I*).

CONCLUSION

Malignant tumours of sweat-glands are often difficult of interpretation in that there may be doubt as to their genuine malignancy or genuine origin from sweat-gland.

There exists, however, a number of cases of sweat-gland tumour of undoubted malignancy as evinced by metastases, and recently these have been recognized as a distinct group (Duany) considered by Lever to be of different cellular origin. Twenty-one such cases are on record.

These cases show a marked tendency to metastasize to regional lymph-nodes (20 out of the 21 cases), and to recur after local excision or radiotherapy. Of 11 cases excised locally 8 had recurrences; there is no recorded follow-up of 3 cases. Five cases treated by radiotherapy recurred, 2 cases have no follow-up. There is no recorded benefit from either procedure.

Distribution is widespread, the axilla and arm (6 cases) and the scalp (6 cases) being the commonest sites. Six cases (29 per cent) occurred in areas where apocrine glands are found.

Eleven of the cases were women and 9 cases were men, corresponding to the sex distribution of sweat-gland tumours in general as shown by Duany, 59 per cent occurring in females and 41 per cent in males. The average age of the females was 53 years and of the males 50 years.

The type of sweat-gland tumour which metastasizes is almost invariably an adenocarcinoma with marked acinar and sometimes papillary structure; the type which, in fact, is usually regarded as relatively benign. Not infrequently the microscopical picture of these tumours when first excised is of a benign adenoma, and they often behave as such, with a history of many years' slow growth before signs of malignancy appear. The average length of history in the recorded cases is eleven years. After this long period of very slow growth these tumours, for no known reason but often following surgical intervention, suddenly assume microscopical and clinical appearance of malignancy, recurring shortly after excision, producing regional metastases, and often proving fatal.

The primary growth is usually a solitary nodular tumour, 1–2 cm. in diameter, frequently showing a red or purple tinge. Though the microscopical appearance of such a tumour is of a benign sweat-gland adenoma, it is not sufficient to regard the patient as cured simply by local excision of the growth; a careful follow-up for at least two or three years should be carried out.

Should recurrence take place a very wide local resection should be undertaken, with radical excision of the regional lymph-nodes at the first sign of involvement. Of the 8 cases in which the latter procedure was carried out, 3 were reported well five years, two years, and three months later; 1 case recurred 1½ months after and 1 (probably) 22 months after radical surgery, 1 died twenty-seven months after, and there is no follow-up report on the remaining 2 cases.

SUMMARY

The literature on sweat-gland carcinoma is reviewed, and the rarity of metastases in such cases is stressed.

Twenty recorded cases of metastasizing sweat-gland tumours are listed and a further case reported.

The pathology is discussed. Many sweat-gland tumours which appear microscopically malignant run a very benign course. Rarely a clinically malignant tumour occurs which may, conversely, appear microscopically as a benign adenoma in its early stages.

A careful follow-up in certain cases of sweat-gland tumour is advised, the treatment advocated for metastasizing tumours is wide local extirpation with radical removal of the regional glands.

I should like to thank Mr. N. C. Tanner for permission to publish his case; Dr. G. Allen for the pathological reports; and Dr. B. C. Morson for the photomicrographs.

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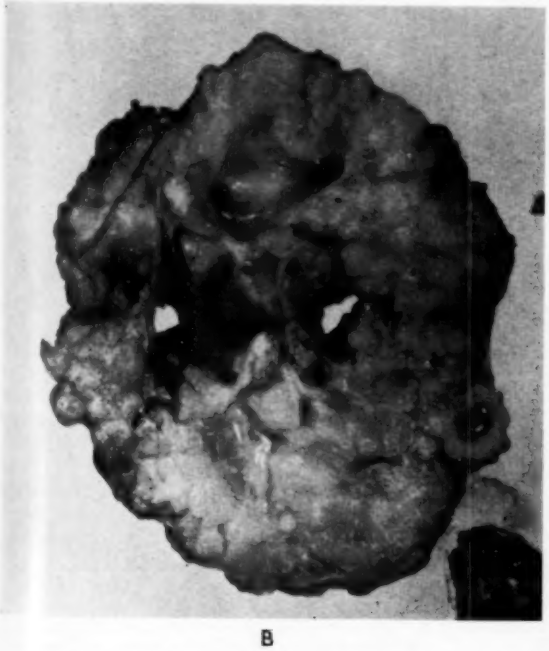
CHONDROSARCOMA SUPERVENING ON DIAPHYSIAL ACLASIS

By ADRIAN E. FLATT, London

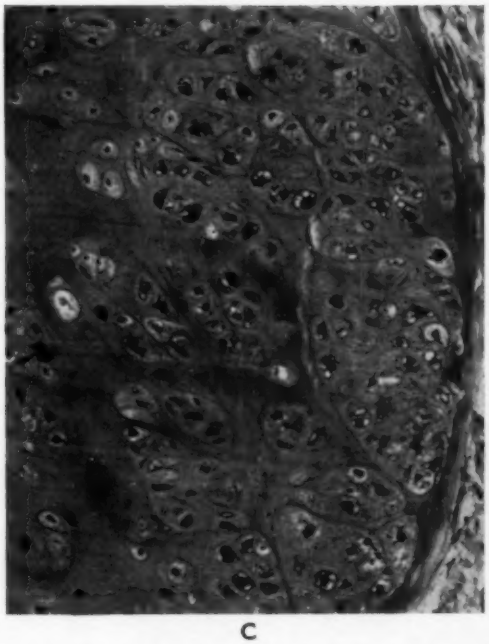
Though diaphysial aclasis or hereditary multiple exostosis is one of the most common of the generalized anomalies of skeletal development met in clinical practice the published estimates of the likelihood of malignant change vary from 5 per cent (Ehrenfried,

Fig. 101.—Pressure erosion of the medial side of the fibula by the partly calcified exostosis arising from the posterolateral surface of the tibia. Other exostoses can be seen.

A



B



C

Fig. 102.—A, Showing the tumour in situ with the lateral popliteal nerve retracted to one side. B, The tumour cut across. C, Photomicrograph (× 92).

1915) to 11 per cent (Jaffe, 1943). It is because of this variation and because of certain features of the case that this record is published.

CASE REPORT

HISTORY.—An unmarried woman aged 25 was first seen in February, 1949, complaining of pain and swelling in the right calf.

For the previous five years she had noticed that the calf was larger than on the left side, but the size had increased during the last year. For the six months before attending hospital there had been an aching pain in the calf, which was made worse by exercise but was also present at night.

At the age of 6 she had an exostosis removed from the medial side of the upper end of the right tibia.

Her elder sister has recently had exostoses removed from both calcaneal bones. No other member of her family has been found to have exostoses and her son born in 1953 is quite normal.

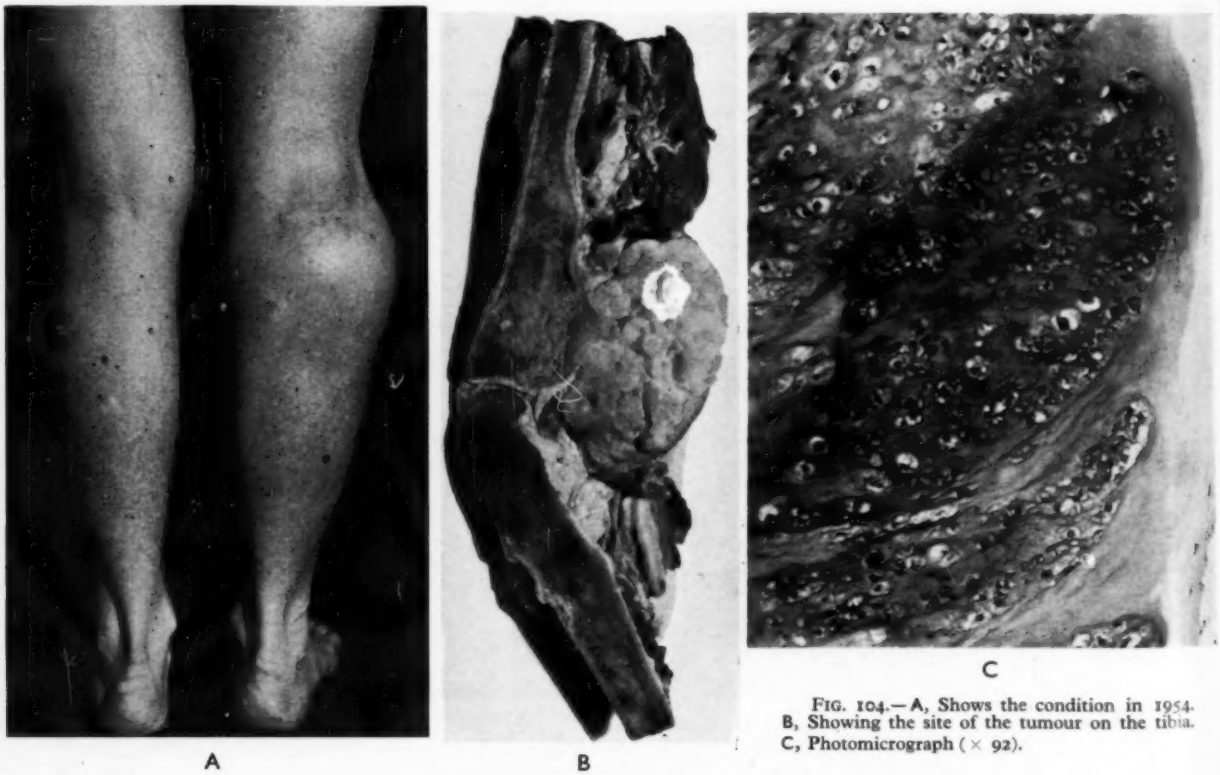
ON EXAMINATION.—Right leg: There was a large, hard mass palpable deep to the gastrocnemius, which appeared to be arising from the lateral side of the tibia. An exostosis was palpable at the lower medial end of the tibia and the remains of an exostosis were also palpable at the upper end.

Exostoses were also palpable on the lower end of the left femur, the lower end of the left fibula, the upper and lower ends of the left tibia, the right iliac crest, the lower ends of the left radius and ulna, the proximal phalanx of the left middle and right fifth fingers, the sternal end of the second right rib, the left clavicle, and the right scapula.

Radiographs of the affected leg (*Fig.* 101) showed multiple exostoses with a large one which was partly calcified arising from the posterolateral aspect of the tibia.

TREATMENT.—The calf was explored on Feb. 24, 1949, through a long lateral incision. To give an adequate exposure the upper 3 in. of the fibula was excised subperiostially and there was found to be a small chondroma on the medial side of the head; the medial surface of the upper end had been eroded by the pressure of the adjacent tumour. The chondroma formation at

FIG. 103.—Two years after operation some ossification has taken place in the periosteum of the fibula. A large exostosis arising from the posteromedial side of the tibia can be seen. This exostosis can just be seen in the lateral view in *Fig.* 101.



A B C

FIG. 104.—A, Shows the condition in 1954. B, Showing the site of the tumour on the tibia. C, Photomicrograph (× 92).

the lateral border of the upper end of the tibia measured 5 in. (12·5 cm.) long by 2 in. (5 cm.) broad. The mass was excised down to and including the cancellous bone of its base. The pathological report showed the tumours from both the tibia and fibula to be ossifying ecchondromata with no invasion and no evidence of chondrosarcoma (*Fig.* 102).

FOLLOW-UP.—The patient made an uneventful recovery and was married within five weeks of the operation. She was followed up at regular intervals until two years after the operation; at this time the wound was soundly healed, was not tender, and there was no swelling. There was a full range of knee movement. The X-ray appearances are shown in *Fig.* 103.

Unfortunately the patient did not return for another three years, being seen next in February, 1954; on this occasion she stated that about two months after the birth of her son in June, 1953, she began to notice a constant aching pain in the leg and a slow increase in size of the calf.

Clinical examination showed a hard, painless lump arising from the deeper structures in the upper and posterior part of the lateral side of the calf; the skin was not attached. (*Fig.* 104.) The X-ray appearance is shown in *Fig.* 105.

In view of these changes the leg was amputated above the knee and pathological examination confirmed the diagnosis of chondrosarcoma (*Fig.* 104, C).

Dissection showed the tumour to be arisng from an exostosis on the posteromedial surface of the tibia and to be spreading laterally. This exostosis is shown in *Fig.* 103.

COMMENT

There are many isolated reports of similar cases in the literature, but no extensive series have been published. O'Neal and Ackerman (1952) report that the age of onset has been recorded as varying between 11 and 59 years, but that the greatest incidence is in the third decade.

There is no history of trauma in this case and although some history of trauma was obtained in many reported cases it is probable that the trauma draws attention to the tumour rather than causes it.

Fairbank (1949) states that malignant change tends to occur in the femur, scapula, and pelvis. The majority of cases reported have appeared in the femur, the next most common site being the pelvis; it appears to be very uncommon for the tibia to be the site of the malignancy.

The difficulties of histological diagnosis of chondrosarcoma are notorious but there appears to be little doubt that at the first operation the tumour which arose from the lateral border of the tibia was completely removed and was benign in character. There then followed a symptom-free period of five years between the operation and the birth of the patient's son. Within two months of delivery the symptoms had begun to be noticeable and were caused by a malignant tumour arising in a different site from the original growth.

Gardner (1937) has previously commented on this association, reporting a case arising shortly after pregnancy and quoting a further case described by Boyer (1814) with a similar relationship.

FIG. 105.—Areas of patchy calcification in the large tumour just prior to amputation.

I would like to record my thanks to Mr. H. Osmond Clarke for permission to publish this record of a case under his care and to Mr. R. F. Ruddick and Mr. A. J. King for the photographic records.

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FRACTURES OF THE EXTERNAL CONDYLE OF THE HUMERUS IN CHILDREN

By J. N. WILSON, London
FROM THE CARDIFF ROYAL INFIRMARY

THE majority of the material for this paper has been drawn from the study of 57 fractures of the external condyle of the humerus in children, treated at the Cardiff Royal Infirmary over a period of four years. The mechanism, age incidence, diagnosis, and methods of treatment have been amply dealt with in previous papers, and the views expressed are fully supported on analysis of the present series of cases. It is therefore not the intention in this paper to describe the full clinical picture of the lesion, but rather to attempt to relate the various radiological types of injury to the complications which can occur, and to discuss treatment to reduce these complications to a minimum.

Table I.—CLASSIFICATION OF FRACTURES OF EXTERNAL CONDYLE OF HUMERUS

Type of Fracture		*Number of Cases*
1. Chip fracture of the condyle		10
2. Fractures of condyle and capitellum		
a. Flake fracture	32	
b. Large fragment fracture	8	
c. Fracture with subluxation	5	
	—	45
3. Comminuted fracture		2
Total		—
		57

CLASSIFICATION

Table I shows how the injuries may be conveniently divided and subdivided into a variety of different types. It will be observed that the majority of these fractures are those involving the whole of the capitellum and a portion of the metaphysis, and it is in this type that a particular interest has been taken.

Chip Fracture of the External Condyle.—*Fig.* 106 illustrates this first type. It may occasionally be a true separation of the epicondylar epiphysis, as is so frequently seen on the medial side ; but, as has been pointed out by authors (Watson-Jones, 1943), this is a rare occurrence because the epiphysis on this side is only present for a very short time. The common lesion is a chip of bone off the external condyle anywhere between the epicondyle and the joint line. In the illustration the fragment is very close to the joint line, and was, in actual fact, intracapsular. These fractures invariably go to non-union and usually give rise to no symptoms.

Fracture of the Condyle and Capitellum.—It will be seen that this type forms the bulk of injuries. It results in a fragment consisting of the capitellum and a third of the trochlea, along with a buttress of the metaphysis from the posterolateral surface, which is sheared off by the nature of the precipitating trauma (Wilson, 1936). This fracture can be further subdivided into three varieties which are described below :—

Flake Fracture : This is illustrated in *Fig.* 107. It has been so called because of the very small nature of the metaphysial fragment. The displacement in the majority of these fractures is slight, but in some cases it may be complete, with somersaulting of the fragment, described and explained very fully in previous papers (Kini, 1942).

FIG. 106.—Showing a chip fracture of the external condyle, with the small fragment lying very close to the joint line.

Large fragment type : This is shown in *Fig.* 108. It is much less common and is nearly always displaced. It may seem rather an unnecessary subdivision, but it is thought that it may be this type which occasionally goes to non-union with a gross deformity in later life.

Fracture with Subluxation : This is an infrequent variety which is shown in *Fig.* 109. It may occur in either the flake fracture or the large fragment type, but is rather more common in the latter. It is interesting to note the forward subluxation of the head of the radius as well as the lateral displacement of the radius and ulna as a whole. This lateral instability can be diagnosed clinically during the course of closed reduction. The sigmoid notch can be felt subluxing into the gap between the trochlea and the capitellar epiphysis. Whether this subluxation occurs probably depends upon the amount of trochlea torn away with the capitellum.

Comminuted Fracture of the Capitellum.—This is a rare injury and an example is shown in *Fig.* 110. The two cases in this series followed the course of a simple undisplaced fracture. Since this

eview was carried out I have seen one similar case go on to non-union, without any evidence of deformity or other clinical abnormality.

COMPLICATIONS

These are listed in *Table II*.

Limitation of Movement.—Permanent loss of movement is rare in these fractures. What limitation does occur is nearly always extension. In only pronation, but in all other cases rotation was full. In only 1 case was there gross limitation of extension—about 50°, and the radiograph showing the position of union is shown in *Fig.* 111. Failure to correct the anterior displacement of the capitellum is probably the explanation of the extension loss. All but one of the cases of limitation of movement occurred in the displaced condylar type of injury. The exception was in a case of chip fracture—the chip later forming a loose body.

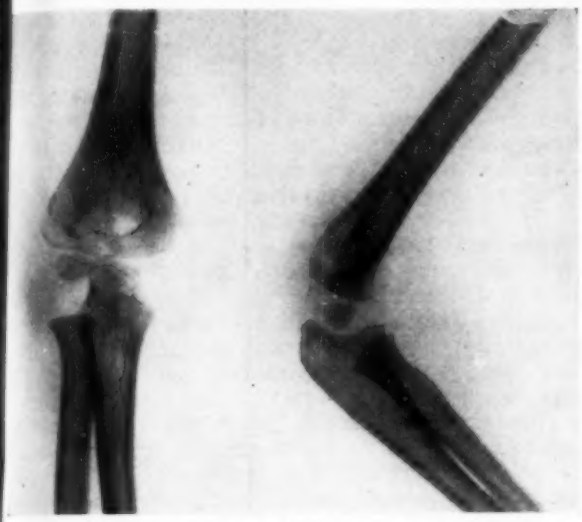

FIG. 107.—An example of a flake fracture of the condyle and capitellum, illustrating the very small nature of the metaphysial fragment.

FIG. 108.—Showing the large fragment type of fracture.

FIG. 109.—Illustrating a case of fracture of the capitellum with lateral subluxation of the radius and ulna.

FIG. 110.—Showing the rare comminuted fracture of the capitellum.

1 case was flexion limited, and that was only in the last 10°. In 1 other case there was slight loss of full

Table II.—COMPLICATIONS

1. Limitation of movement
2. Deformity
3. Delayed ulnar neuritis
4. Non-union
5. Loose body
6. Avascular necrosis

Deformity.—*Table III* lists the deformities which may occur.

Cubitus Valgus.—This is probably much less common than is generally thought. There was only 1 case of severe cubitus valgus (30°), and this was in a case of non-union. Other cases were not more than 5° and presented no deformity.

Prominence of the External Condyle.—This was observed to some extent in all cases where union

occurred with some lateral displacement, and has been described as a common result after conservative treatment (Lee, 1942). It does not form an ugly disfigurement.

Fishtail Deformity.—This can only be detected radiologically and *Fig*. 112 shows a typical example.

FIG. 111. - Radiograph of a case of malunion which resulted in considerable restriction of extension of the elbow.

development of osteo-arthritis in later life. *Fig*. 11 shows such a case presenting with arthritic symptom at the age of 54, with a history of a fracture of th elbow at the age of 7.

Ulnar Neuritis.—This is an accepted lat complication of this fracture and considered to b due to the strain put on ulnar nerve by a valgu resulting from malunion. On reviewing 27 cases o ulnar neuritis it was found that only 1 of the case followed an ununited fracture of the external condyle and this was associated with an ununited fracture of the medial epicondyle. Two other cases showed valgus deformity, but in both these there were fractures of the medial epicondyle accompanying the injury on the outer side. It is suggested, therefore, that cubitus valgus by itself is unlikely to lead to an ulnar nerve lesion, but must be associated with an injury or irregularity on the inner side of the joint. It is a well-known fact that nerves will tolerate a considerable degree of stretch slowly without any palsy occurring, and it seems unlikely that the small amount which occurs in cubitus valgus could produce a lesion. *Fig*. 114 illustrates a case of fracture of the medial epicondyle and displacement of the capitellum in which delayed ulnar nerve signs might well be expected.

Non-union.—This is much more rare than is generally realized. Only 1 example has been found in the present series. The literature is confusing on the incidence of non-union. McDonnell and Wilson

FIG. 112.—Radiographs showing the development of fishtail deformity of the lower end of the humerus. Note the early fusion of the epiphysis on the affected side. A, A.P. view shortly after the injury; B, Comparison views six years later.

FIG. 113.—Radiograph taken forty-seven years after a probable fracture of the capitellum and condyle, showing arthritic changes superimposed on an old fishtail deformity.

It occurs in all cases where the reduction has not been accurate and has resulted in a gap between the trochlea and the trochlear portion of the capitellar fragment. It is more likely to occur in a fracture associated with subluxation. It is reasonable to suppose that this deformity might predispose to the

Table III.—DEFORMITIES

1. Cubitus valgus
2. Prominence of the external condyle
3. Fishtail deformity of the lower end of the humerus

(1948) describe 4 cases in 33 fractures—all four being untreated. Other authors advise open reduction in all condylar fractures with displacement—presumably to avoid the possible disaster of non-union (Blount, Schulz, and Cassidy, 1951, Davis, 1951; Speed and Boyd, 1937; Raney, 1950), but there is no clear distinction between types of displacement or indication which fractures are more likely to go to non-union.

The cause of the condition has always been rather a mystery. Wilson (1936) observed that the

united fragment often becomes larger than normal, and therefore concluded that loss of blood-supply could not be considered a factor. The case where complete rotation of the fragment has taken place and remains unreduced, is understandable, and will always go to non-union unless the rotation is corrected. The example available is not of this type. *Fig.* 115 shows the radiograph of the fracture immediately after coming out of plaster about a month after the injury. There is some lateral displacement with fragmentation of the metaphysial portion, which is of the large fragment type. There is no obvious subluxation of the radius and ulna. It is the type of fracture which usually unites with some irregularity, but which occasionally goes on to non-union. *Fig.* 116 shows the position a month later, when it will be observed that there is much more anterior displacement of the fragment, and that the head of the radius has come forward with it. *Fig.* 117 shows established non-union four years later. Is it not possible that the cause of the non-union in this type of case is the progressive forward tilt of the capitellar fragment, which opens up the fracture surfaces posteriorly? I have had the opportunity of observing this occurrence in 2 other cases, one of non-union, and the other of delayed union.

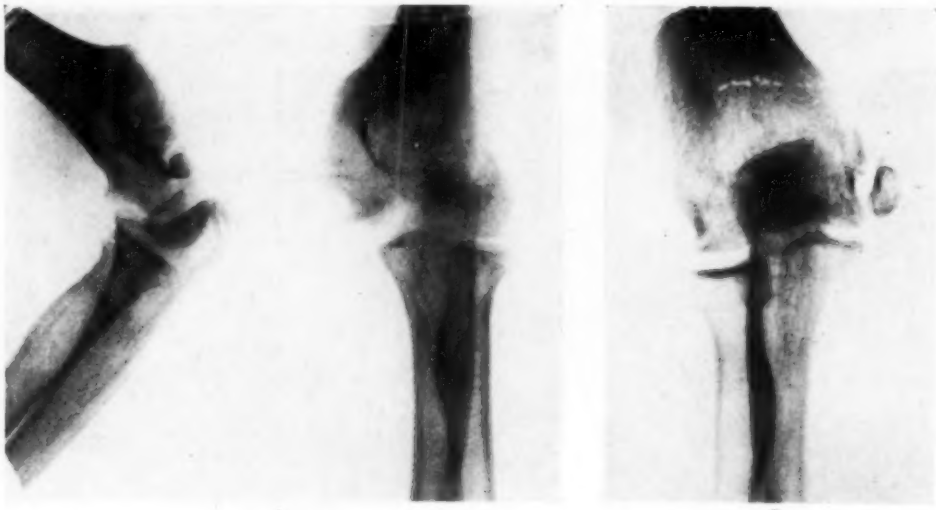

FIG. 114.—Showing a case of fracture of the external and internal condyles, in which one might anticipate ulnar nerve neuritis in later life. A, Position before reduction; B, Showing the ununited medial condyle six years after the injury (reproduction is reversed).

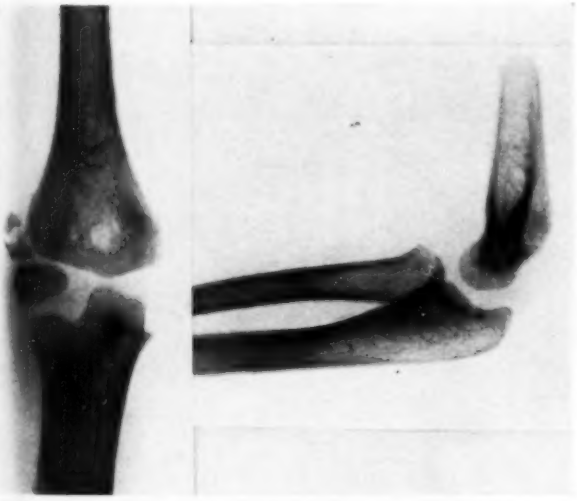

FIG. 115.—A case of non-union. Radiograph one month after reduction.

FIG. 116.—The same case as in *Fig.* 115 two months after reduction, showing the progressive forward displacement of the capitellar fragment, with anterior subluxation of the head of the radius.

Loose Body.—This occurred in a case of chip fracture of the external condyle which was shown in *Fig.* 106 as an example of this type. If the fracture is low enough it may be intracapsular and produce the appearance shown in *Fig.* 118. This loose body was removed and found to be quite free in the joint.

Avascular Necrosis.—This has been described by McDonnell and Wilson (1948) and thought to occur occasionally in flake fracture, where the

blood-supply to the metaphysial fragment must be very small. They also recorded a case following open reduction, which they attributed to the excessive denuding of the fragment. *Fig.* 119 shows the initial radiographs of a case which presented with a very slight flake fracture of the external condyle. The child apparently made a full recovery from this injury, but eight months later came up again complaining of pain and stiffness in the elbow following another fall. *Fig.* 120 shows the typical changes of osteochondritis present at that time. It is interesting to note that these changes persisted for a long time after the elbow had become clinically normal, which supports a similar observation made by Mason (1953) in a recent paper.

FIG. 117.—Established non-union four years later.

FIG. 118.—Showing an example of loose-body formation in chip fracture of the external condyle.

FIG. 119.—A case of avascular necrosis of the capitellum. Radiograph showing a very faint flake fracture.

FIG. 120.—Established changes of avascular necrosis eight months later.

Table IV.—INDICATIONS FOR OPERATIVE TREATMENT

1. Irreducible fractures
2. Unstable fractures : —
   a. With lateral subluxation
   b. With progressive forward displacement

TREATMENT

Conservative.—There is no doubt that the majority of these fractures can be treated conservatively. Even the fragment which is completely rotated can sometimes be reduced by manipulation, and the methods of carrying out the reduction with the forearm in the adducted position, followed by pronation to maintain position, has been described by a number of authors (Hopkins, 1932 ; Kini, 1942). The chip fractures and the fractures which are stable and have only minimal displacement, should all be treated conservatively.

Operative Treatment.—The indications for open reduction are given in *Table IV*.

Irreducible Fractures.—These are the cases where there has been rotation and somersaulting of the

capitellar fragment. I consider that it is nearly always necessary to reduce these fractures by open operation, although cases have been reported treated successfully by closed methods.

Unstable Fractures.—Displaced fractures treated by closed reduction will probably develop a fishtail deformity to some extent. Accurate reduction by open operation is the only sure way of avoiding this. However, the deformity will not be great provided that there is no lateral subluxation of the radius and ulna, and the presence or absence of subluxation is an important factor in making the decision to operate in the borderline case. The evidence of instability allowing forward displacement of the fragment is an indication for open reduction, and I think it is important that these fractures should be checked by radiography after three weeks and again at six weeks, in order that this displacement should not be missed.

Internal Fixation.—The method of open reduction is well known. It may be difficult to orientate the fragment, but care must be taken to insure that the reduction is anatomically perfect. It is a personal opinion that it is not possible to maintain this reduction without internal fixation. I have found sewing the fragment into position a tedious procedure, and I have never been happy about its security (*Fig.* 121). A simple method of internal fixation has been used successfully in 10 cases, one of which is shown in *Fig.* 122, showing the unsuccessful attempt at closed reduction. *Fig.* 123 illustrates the position obtained by open reduction, using a Pidcock pin to maintain the fragment in place. This pin is easily introduced by starting it held in a guidewire holder while the fragment is held reduced by a single-toothed volsellum forceps. Once the pin has gained a start

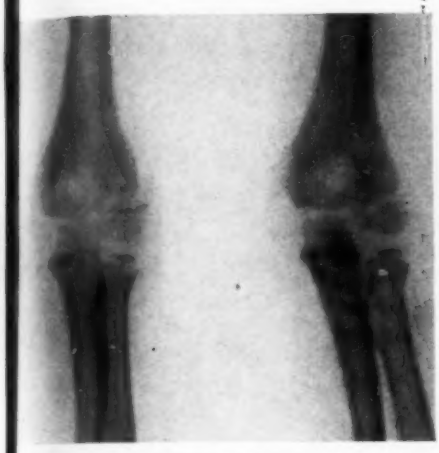

FIG. 121.—Illustrates the amount of slip which can occur after open reduction, when only simple suturing of the fragment and soft tissues is carried out.

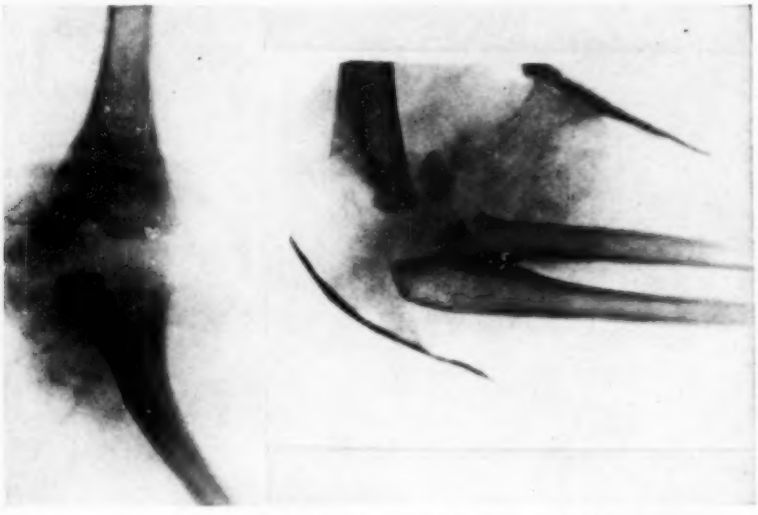

FIG. 122.—Radiograph of a condylar fracture before open reduction.

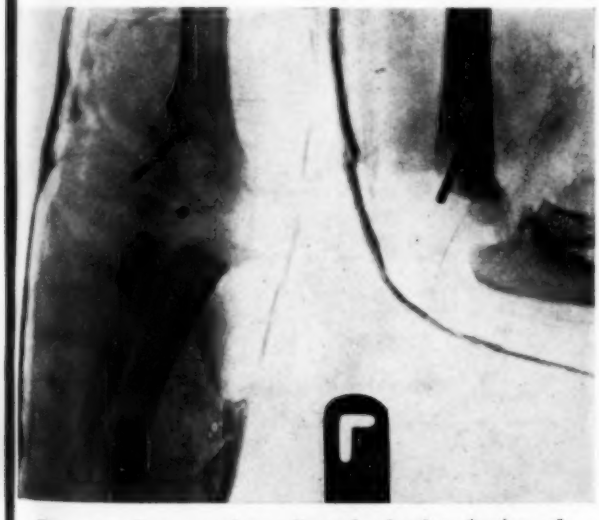

FIG. 123.—Post-operative radiograph showing fixation of fragment with a Pidcock pin.

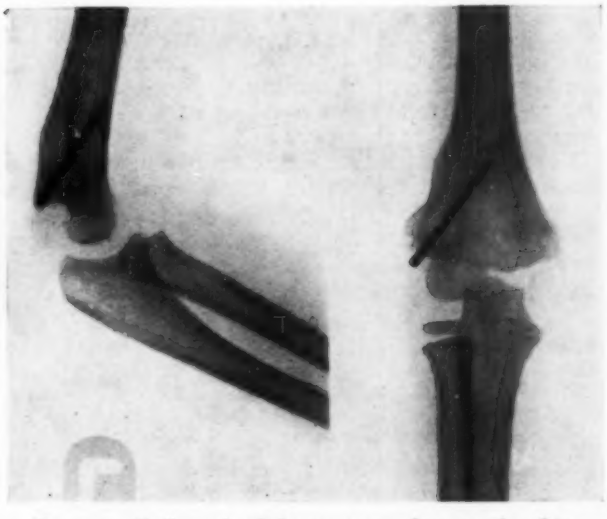

FIG. 124.—Radiograph of the same case four months after operation.

in the bone it can be easily tapped home with a small mallet. It gives excellent fixation and, although on occasions the pin has started to back out after a few weeks and has had to be removed, it holds the fracture until union is sufficiently solid to prevent re-displacement. *Fig.* 124 shows the result four months after operation.

SUMMARY

A study of 57 fractures of the external condyle of the humerus in children has been made.

The fractures can be divided into three main types.

The association between the type of fracture and its sequelæ has been discussed.

An outline of the management of the fracture is given and a simple method of internal fixation described.

I am indebted to Mr. Dillwyn Evans for allowing me to review cases under his care, and to the staff of the Orthopædic Department of the Cardi Royal Infirmary for their help in tracing patient I am grateful to Miss Wales, of The Princ of Wales Orthopædic Hospital, Rhydlafar, for th illustrations.

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EXCISION OF AN ANEURYSM OF THE RIGHT SUBCLAVIAN ARTERY

CASE HISTORY AND DISCUSSION

BY G. E. MOLONEY, OXFORD

" Ce n'est pas un chapitre de thérapeutique, c'est un martyrologue."—DELBET (1889).

THE early history of arterial ligation for subclavian aneurysm reads like a battle casualty list. Souchon (1895) collected up to that time all the recorded cases of subclavian aneurysm submitted to any form of operative treatment, and out of 56 cases there were only 8 recoveries. Gordon-Taylor (1950) records the instances of ligation of the innominate artery for subclavian aneurysm, and some 19 patients had died before Smyth (1869) broke through the fatal barrier by an initial ligation of the innominate and carotid arteries followed by a late enforced ligation of the vertebral artery for repeated hæmorrhage. From Mott (1818) to Moynihan (1898) some 33 ligations of the innominate artery alone or combined with the common carotid artery saved 5 patients with subclavian aneurysm. Victory was hard won. Repeated hæmorrhage particularly, together with sepsis and cerebral catastrophes, were the principle causes of death. In this century recoveries have been more frequent but repeated hæmorrhages have still been a problem. Successes have notably followed multiple ligatures where innominate and carotid are both tied and proximal or distal subclavian or axillary ligatures may have been added. After ligation of only one artery the difficulty has arisen so often of dealing with a recurrence of the aneurysm or with a second hæmorrhage due to the great volume of blood by-passing the proximal ligature by way of the large collateral branches of the second part of the subclavian artery. In the case presented here this same problem arose, as an initial ligation of the right subclavian artery for a large aneurysm of the first and second parts was followed six months later by a recurrence of the aneurysm. A distal ligation, and subsequent packing of the cavity of the aneurysm failed to induce healing after a spontaneous rupture of the aneurysmal sac had occurred, and an excision of the aneurysm was necessary to establish a cure.

FIG. 125.—The large expansile swelling in the right supraclavicular region, immediately prior to the first operation.

A notable feature in this case is the unusual cause of the aneurysm, which resulted from direct erosion of the vessel wall by contiguous tuberculous lymphadenitis. This is such a rare lesion of the

subclavian artery that I can find no record of a similar case.

CASE REPORT

F. C., a retired army officer of 62, was referred to me by Dr. A. M. Cooke on May 15, 1952, complaining of a gradual enlargement of glands in the right supraclavicular triangle. The glands were attached to the skin, irregular in surface, mostly fused into one mass, and firmly adherent to the deeper structures. A physical examination, radiography of the chest and barium meal, W.R. and Kahn reactions revealed no source which might account for the swelling. I performed a biopsy, only the upper portion of the lesion, which was markedly necrotic, being removed, the lower portion being densely adherent to the deep veins and to the brachial plexus. The wound healed without discharge. The histological report showed that the lesion was a tuberculous lymphadenitis with a spread into the surrounding fibrofatty tissue. Small numbers of acid-fast bacilli were found in the section.

The right supraclavicular region remained unaltered during the next six months, after which there developed a further small swelling on the same site, but another six months went by before a rapid alteration of the size of the swelling made the patient return to his doctor, who speedily sent him to me. The patient said that a week previously the swelling in the right supraclavicular region became much larger and increasingly painful. The day before his visit the swelling had increased markedly in size. There was a large mass in the right supraclavicular region (*Fig.* 125) which pumped alarmingly, with little more than skin between the patient and the grave. He wanted me to open the ' abscess ' and let him get back to his gardening. A right Horner's syndrome was present. Both right and left pulses at the wrist were normal and equal. A radiograph showed a soft-tissue mass extending just inside the thoracic inlet on the right side, with displacement of the trachea to the left (*Fig.* 126). Arrangements were made for urgent operation.

FIRST OPERATION (June 6, 1953).—Under a general anæsthetic an incision was made on the upper portion of the chest the shape of a sign of the Cross, with the long limb running down the midline from about 2 in. above the sternum to the level of the junction of the fourth rib. The cross-piece of the incision went for about 3 in. on the right side and 2 in. on the left over the clavicles. A removal was made of the inner 2 in. of the clavicle with the help of the Gigli saw, and of the right upper portion of the sternum to the level of the third rib with the help of the sternal chisel. There was a large aneurysm extending into the chest, almost to the angle of Louis, but it was just possible to approach the point of branching of the innominate artery. The subclavian artery was displaced by the aneurysm so that it passed directly backwards from the point of origin. After a preliminary compression of the right subclavian artery had been seen to produce a big reduction in the pulsation and size of the aneurysm, the right subclavian was encircled and then tied with two stout ligatures of braided nylon, a small gap being left between ligatures. The wound was then closed about a drain, as there was moderate oozing.

A valuable safeguard in case of sudden severe bleeding, and one which gave confidence in dissecting, was the introduction of a cannula into the left radial artery which was attached to an apparatus for arterial transfusion. During the operation two pints of blood were slowly introduced by this method. Fortunately there was no severe bleeding calling for rapid arterial transfusion, but it was a great comfort to know that this method of resuscitation was ready should disastrous bleeding occur.

POST-OPERATIVE PROGRESS.—Two days after operation the pulse in the right wrist, which had been absent, returned faintly. The aneurysm quickly hardened and shrank owing no doubt to thrombosis followed by absorption and fibrosis.

The need for a detailed blood examination had revealed an unusual blood condition which continues to intrigue our hæmotologists, one consequence being a tendency to ooze both during and after operation, and occurring on each occasion. In spite of drainage he developed a hæmatoma of his wound, and in spite of

FIG. 126.—Radiograph showing a soft-tissue shadow in the right side of the thoracic inlet with tracheal displacement to the left due to the aneurysm.

chemotherapy he developed a low-grade infection of the bone. The sinus at the lower end of the wound did not heal for eight weeks and not until a small sequestrum was removed. The right subclavian region returned almost to normal dimensions, hopes being earnestly expressed that it would remain so.

Four months later he went for a holiday to Wales, telling us subsequently that just as he was leaving home he noticed that a small swelling had reappeared in the right supraclavicular region. Within two days his aneurysm suddenly blew up again to its previous large dimensions. Only the foggy weather at that time prevented his naval friends from returning him by helicopter, but he made the return journey as quickly as he could by ambulance, arriving at the Radcliffe Infirmary on Oct. 21. The aneurysm was again markedly pulsatile, the skin over it being stretched and thinned and ominously dark.

SECOND OPERATION (Oct. 22).—That night I ligatured the first part of the axillary artery through the customary incision below the clavicle. The previous operation and the pressure of the aneurysm above hindered the exposure a little. These ligations reduced the pumping of the aneurysm slightly, but one felt that nothing further could be done at that stage, with the aneurysm occupying most of the right subclavian region.

The next day the pumping seemed only a little less, but 48 hours later there was distinctly less pulsation. The skin over the site of the aneurysm had become deeply pigmented, and markedly stretched, and seven days after operation it gave way. Fortunately a good cap of blood-clot had formed which held. Two days later bleeding began, very quietly at first, through the area of ulceration. I was summoned, and easily controlled the bleeding by packing between the skin edge and the blood-clot, hoping that further clotting would result. On removing the packing three days later further brisk bleeding occurred, which was again readily controlled by repacking.

THIRD OPERATION.—I still had hopes that a cure by thrombosis might occur, but, growing less optimistic, decided to remove the pack a week later under anæsthesia. When this was done, further heavy bleeding occurred, so

I scooped out all the accessible clot with a finger, which released a really good head of blood, and then with gauze packing, filled the depths of the aneurysm, which gave excellent control. In the meantime there was a measure of security and it was hoped that the cataract might be permanently dammed by ensuing thrombosis and granulation. But in the few days previous to this the patient had developed pyrexia and moderate pain about the site of the aneurysm, and the tissues had become œdematous and pink, indicating that infection was creeping into the area. The outlook had become much more

FIG. 127.—Showing the mobilization of the aneurysmal sac which allowed access to the large branches of the subclavian lying behind the aneurysm.

serious and at that time all that could be done was to control the bleeding by packing, and to treat the infection by chemotherapy. A *Str. fæcalis* sensitive to penicillin and aureomycin was attacked by these two antibiotics, with a rapid resolution of the cellulitis.

In view of this recent infection and of the previous failures with packing to control the bleeding and allow healing, I was not optimistic of achieving this end except by an excision of the aneurysm with ligation of all the deep branches passing into it. So arrangements were made for probable aneurysmectomy at the time of removal of the pack.

FOURTH OPERATION (Nov. 27).—Excision of right subclavian aneurysm. Under a general anæsthetic an incision was made over the left femoral artery and a cannula placed into it to establish an arterial transfusion. This once again added greatly to the patient's safety and to surgical confidence during the subsequent dissection. This arterial transfusion was set up and attended to on both occasions by Dr. B. Dwyer and Mr. A. M. Gardner. The pack already in the cavity of the aneurysm was hopefully removed but heavy bleeding resulted, so the cavity was repacked tightly and the dissection begun.

An incision was made in the line of the sternomastoid above the aneurysm, carrying the cut downwards through the old scar tissue to the level of the third rib. A further incision was made encircling the outer side of the aneurysm. The dissection was tedious, much of it being through old scar tissue. In the upper region the aneurysm was freed from the sternomastoid muscle and the common carotid artery. The internal jugular vein was densely adherent, so that it was necessary to tie the vein above the aneurysm, which could then be retracted outwards to some extent. After further dissection at a lower level the jugular vein was tied, and a segment of it was gradually peeled downwards off the deeper structures,

FIG. 128.—Showing the scarring after the three operations. 1, Cross incision for ligation of the subclavian; 2, Ligation of axillary; 3, Excision of aneurysm.

particularly from the brachial plexus. A dissection at the lower level of the great vessels was then made, and the site at which the subclavian had been ligatured was defined once again. This was found to be securely tied with no evidence of a lumen remaining in it. The internal mammary artery had been tied at the first operation. After the great vessels had been dissected below, and the aneurysm freed above, it was possible to approach the posterior aspect where the various branches came into view (*Fig.* 127). The thyrocervical and costocervical trunks, and finally the vertebral arteries, were all brought into view. As these branches were all patent a large volume of blood had been passing into the aneurysmal sac from them. The various branches were dealt with partly by the use of an aneurysm needle, and partly by forceps, depending on the access and length of the vessel, linen thread being used for ligature. The vagus nerve had been found, but the right recurrent laryngeal nerve was not identified in this dense scar tissue. The skin incision was closed as far as possible, the cavity recently occupied by the aneurysm being treated by packing. A drain was placed at the anterior end of the long wound.

POST-OPERATIVE PROGRESS.—The patient was little disturbed by the operation, which lasted about 3½ hours. Two days later the cavity at the site of excision was repacked, and further repacking was done at intervals while the wound slowly healed. The site of drainage anteriorly remained as a sinus for four months, during which time the various ligatures to the vessels which had fed the aneurysm gradually were discharged along the sinus, which has now healed (*Fig.* 128). He has satisfactory movement of his arm, with abduction almost to a right angle, having no disability, being able to dress himself, drive his car, and go about his ordinary duties.

Immediately after the last operation the patient's voice gave a clear indication that the recurrent laryngeal nerve, which before had been reduced in function by the pressure of the aneurysm, had now been completely interrupted as it lay in the dense scar tissue. Laryngoscopy later showed an immobile right vocal cord. But at the present

time the hoarseness has improved to such an extent as to be almost unnoticeable. The Horner's syndrome remains.

The patient has an unusual form of anæmia which has required special blood for transfusion, and in spite of exciting much interest in Drs. MacFarlane and Pickles of the Hæmatological Department, the nature of the disorder is still uncertain. At the time when the skin over the

FIG. 129.—Posterior view of the specimen showing the stump of the right subclavian artery on the left of the picture with the patent four main branches. The false aneurysm arises anterosuperiorly opposite these branches, and the opening of the aneurysmal sac onto the skin is seen on the right of the picture. The sac was opened in front and below.

aneurysm gave way and there was severe oozing the hæmoglobin dropped to 33 per cent, but the level was restored by transfusion and it is now over 65 per cent, which is a satisfactory level for him.

THE SPECIMEN (*Fig.* 129).—The specimen consists of a portion of the subclavian artery about 2 cm. long, with a false aneurysm arising from a large deficiency of the anterosuperior portion of the junction of the first and second portions of the artery. A glass rod could be passed from the proximal subclavian lumen through a small orifice into the aneurysm. The distal side of the subclavian could not be identified. The lumen of the four main branches of the subclavian were all communicating with the aneurysm. There was a large opening from the aneurysmal sac through to the skin. The overall measurement was $8 \times 4 \times 4$ cm.

HISTOLOGY.—Two small lymph-nodes taken from the back of the aneurysm show reactive hyperplasia with no evidence of tuberculosis. A section of the aneurysm shows an internal lining of organizing blood-clot with an external layer of fibrous tissue containing a scattered collection of hæmosiderin macrophages and often a small area of lymphoid tissue.

DISCUSSION

Frequency of Sac Excision.—The first successful excision of an aneurysm of the right subclavian artery has been attributed to Schopf (1891) of Vienna, but this nearly solidified aneurysm was mainly axillary, the approach being infraclavicular, and Moynihan (1898) would not class it as a 'subclavian'. Moynihan excised an aneurysm of the third part of the right subclavian artery, his ligature being passed distal to the vertebral artery. This patient developed a severe secondary hæmorrhage on the fifty-ninth day after operation which called for ligature of the innominate artery, but the patient died one hour after this latter operation. His case was therefore not carried through to a successful conclusion.

Braithwaite (1920), whilst attempting to ligate the first part of the right subclavian for an aneurysm of the first and second parts, accidentally ruptured the sac. He controlled the bleeding with a finger through the sac into the afferent vessel. After dissecting the afferent and efferent vessels he clamped them and excised the sac, the patient making a complete recovery and returning to his work as a coalminer. This was the first recorded successful excision of a spontaneous aneurysm of the right subclavian artery.

The left subclavian artery, though much the same in some respects, presents rather a different problem of approach. The first successful excision of an aneurysm of the left subclavian artery was undoubtedly that of Halsted in 1892. This was subclavo-axillary in site, being a true aneurysm. A traumatic aneurysm on the left side was excised successfully by Dünow in 1904. Saigo (1906) performed the first successful excision of a traumatic aneurysm on the right side in two stages, and this was in fact the earliest successful excision on the right side of any type of aneurysm. He was followed by Herzen (1910) with a success with a traumatic aneurysm on the right side. A further successful excision of a left-sided traumatic aneurysm was by Franz (1911). Von Haberer (1915, 1916) had the greatest success of all, excising one on the right and three on the left, following up with an end-to-end suture of the left artery in two instances. Makins (1919) recorded traumatic aneurysms of the subclavian vessels in 24 patients after World War I, 13 arterial and 11 arteriovenous, but the few in whom an excision was attempted died on the operating table. There followed a series of successful excisions of traumatic aneurysms on the left side by Pfanner (1922), Cassanello (1922), Chianello (1925), Schindler (1928), and Arce (1928). An aneurysmectomy with lateral suture of the artery was performed by Lee, Mitchell, and Peacock (1934). Muller (1935) performed a further successful resection on the left side, and Temple (1950) reported a case of excision of a spontaneous left-sided aneurysm. The present case is the fifth instance that I can find in the records of a successful resection of a right-side subclavian aneurysm.

Rundle (1937) observed that 3 instances of excision of aneurysms of the innominate artery have been described. Thus it is seen that a resection of an aneurysm of innominate or subclavian artery is a rare operation, and one into which the surgeon is usually forced by circumstance.

Type of Operation.—Halsted (1924) wrote of tying the left subclavian artery for aneurysm, "The moment of tying the ligature is a dramatic one. The monstrous, booming tumour is stilled by a tiny thread, the tempest silenced by the magic wand." But for how long? Is the booming stilled for ever? May the tempest roar again? Yes, well it may. In the records of Gordon-Taylor (1950) ligature of the innominate for subclavian aneurysm was done in this century in 31 instances, resulting in 23 recoveries with 8 deaths, nearly a reversal of the figures of cure and mortality for the previous century, but there is still a death roll of 25 per cent. Further analysis

shows that single ligation of the innominate artery resulted in 6 recoveries and 5 deaths, whereas multiple ligation of the innominate and common carotid and perhaps subclavian and vertebral in 20 instances resulted in 17 recoveries with 3 deaths.

So often the records show that single ligation may be followed either by an inadequate reduction of the aneurysm, or, if reduced, a later recurrence of the aneurysm, well instanced by Stonham's (1902) ligation of the left subclavian artery, Oldfield's (1944) ligation of the right subclavian, and the present instance. A severe secondary hæmorrhage, especially if sepsis intervenes, is also more frequent following ligation of only one vessel. Multiple ligation in the form of proximal and distal ligatures, and ligation of the vertebral artery if accessible, is clearly the more satisfactory. It is irresistible to conclude from this that if it is necessary to tie off the main arteries to the sac to achieve control, why not excise the sac entirely, and so deal with every vessel entering the sac? This is not a new thought, for Halsted (1892) remarked, " I find practically but one comment from surgeons in the results, viz., if absorbable sutures had been used and if the coats of the artery had not been divided, the mortality from secondary hæmorrhage might have been less. *I would suggest, rather, that the aneurysm be excised*". Moynihan (1898) also extolled the soundness of excision of the aneurysm.

Lindskog (1946) also, in speaking of aneurysms in general, advises that " The ideal treatment of an aneurysm whether traumatic or spontaneous is a Matas endo-aneurysmorrhaphy or proximo-distal ligation and excision of the sac". With the subclavian artery the Matas operation is well nigh impossible to perform and Mason Brown (1948) warns that " In the larger aneurysms excision of the sac may damage important collateral channels or nerves embedded in its wall, and if the sac is not excised it is absorbed in the course of time and does no harm, and it is safer, except in very small lesions, to leave the sac alone". Shumacker and Carter (1946) say excision of the sac of an aneurysm is followed in some cases by impairment of circulation. But it must be pointed out that in this instance proximal and distal ligation did not control the aneurysm and the only route to the large collaterals feeding the aneurysm was blocked by the aneurysm itself, making excision imperative. In general it would appear that proximal and distal ligation together with that of any other large channel will be sufficient to cure most subclavian aneurysms, but occasionally it may be necessary, in special circumstances, to excise the sac.

The Best Proximal Point for Ligation.—The piece of artery should be as healthy as possible, and this demand, or inaccessibility, or the proximity of the aneurysm may drive the operator back on to the innominate artery to find a satisfactory place for ligature. But the evidence indicates that it is best to avoid tying the innominate artery if possible, on the grounds that ligation of the innominate alone cures only half the cases, the recurrence rate being high, and it produces an appreciable incidence of deaths from cerebral causes, being 16 per cent in Lindskog's (1946) analysis of 58 cases.

The Possibility of Distal Gangrene.— There need be no fear of gangrene of the hand in tying the innominate artery for there is not a single such case recorded as a result of this measure, owing to the liberal collateral circulation about the shoulder. But the risk of cerebral catastrophe may have to be taken if circumstances dictate that it is necessary to tie the innominate artery.

The possible development of gangrene of the limb from interference with the subclavian is of great moment. De Bakey and Simeone (1946) showed that in war wounds requiring ligature of the subclavian artery, 28·6 per cent of 21 patients developed a gangrenous limb requiring an amputation at some level or other. But they point out that such figures are fallacious in that the injury which caused the ligation may also destroy the usual collateral vessels, and the patient may have been in a poor general condition from blood-loss from wounds, with general anoxæmia. But it would appear from such experience that it is best to wait, if the lesion is not an urgent threat to life, to allow a collateral circulation to develop which will almost certainly save the limb. Freeman (1946) says that gangrene is very rare following operations for traumatic aneurysm and only 1 case occurred in the entire series of patients in the three vascular centres of the U.S. army, as a result of the policy of waiting and sparing collaterals. In the present case the subclavian with all its collaterals and the first part of the axillary were both tied and still the patient did not develop gangrene, and he now has a distinctly palpable pulse at the right wrist. Times of waiting differ with authors (Mason Brown, 1948) from one to four months, and obviously the longer it is possible to wait the better.

Use of Frozen Grafts.—In arterial damage of all sorts, excision of the lesion with end-to-end suture where possible is a common and successful practice, and where ends cannot be brought together the frozen arterial graft is developing a place. So in lesions of the subclavian vessels where there has been little time for development of collateral circulation or where the collaterals may be deemed inadequate, arterial grafts, such as those proving so successful in bridging the gap between the trunk and legs following the excision of an aortic aneurysm, may well be equally successful in joining the circulation of trunk and arm.

The Operative Approach.—The best operative approach for the innominate and right subclavian arteries would appear to be through the bed of the inner part of the right clavicle and right upper sternum. Before I embarked on both the operation of right subclavian ligation and of aneurysmectomy, cadaveric dissections were made and an approach from the posterior aspect was tried, and it proved most difficult. In the actual operation of aneurysmectomy the attack from in front and above gave good access. Nelson (1932) quoted a case of Alexander's where he approached a right subclavian aneurysm by a posterior route, and finding it unsatisfactory had recourse to an anterior approach.

The left subclavian artery presents a different problem, being a longer artery with no preliminary innominate, and it is more deeply placed. Temple (1950) has recorded the only case in which a left subclavian aneurysm was approached directly by

posterior thoracotomy through the bed of a resected fifth rib. In this instance the aneurysm was entirely intrathoracic, there being neither tumour nor unusual pulsation in the neck. He makes a good case for a transpleural approach in such an instance, and for the left subclavian generally a transthoracic route alone, or combined with a supra- or transclavicular approach, in cases where the second and third parts of the subclavian are involved, is probably the best method.

The Use of Arterial Transfusion.—The final point for emphasis is the use of an arterial transfusion as a safeguard against severe hæmorrhage. Large quantities of blood can be introduced at a great rate by this method, and even after a severe blood-loss a rapid resuscitation can be achieved.

SUMMARY

A case of an aneurysm of the right subclavian artery due to erosion by adjacent tuberculous lymphadenitis is recorded.

The stages of treatment are described, final control being achieved only by an excision of the aneurysm.

There follows a discussion on the frequency of the condition, the types of operation favoured, the site for proximal ligation, the chances of gangrene to distal parts, the possible use of arterial grafts, the operative approach and the use of an arterial transfusion.

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EXPERIMENTAL SURGERY

THE REPAIR OF ARTIFICIAL ULCERS IN THE URINARY BLADDER OF THE CAT

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IT is well established that many tissues of the body are capable of undergoing regeneration or repair. Bizzozero (1894) classified the various types of specialized somatic cells in man on the basis of the degree to which they have the power to divide by mitosis. In his classification, cells comprise three types—labile, stable, and permanent. The labile cells are those which normally multiply throughout their life, and they include skin, the epithelia lining the alimentary, respiratory, and urinary tracts, and cells of tissues such as bone-marrow and lymph-nodes. The stable cells are those which normally do not undergo multiplication after the body has reached its adult stage, but are capable of mitotic division following injury ; included in these are the parenchymatous cells of liver, pancreas, and kidney. The permanent cells are those which lose their power of multiplying at the time of birth ; these are largely confined to the neurones of the nervous system.

A considerable amount of work has been carried out on the regeneration of cells in the labile group, especially those of the epidermis, though little attention has been paid to those of transitional epithelium.

Recently Johnson and McMinn (1955) showed that, when transitional epithelium was transplanted, it behaved in a manner which was unlike that of any other stratified epithelium, in that it showed itself capable of rapid growth by mitosis at a very early stage following its implantation to a new site. Since it has been shown in the case of skin that the growth which occurs in the repair of lesions (Arey, 1936) is similar to that which occurs following its

transplantation (Medawar, 1944), it was decided that the manner of growth of transitional epithelium in the repair of bladder ulcers should be compared with that which occurred on transplantation. The lack of detailed studies on the repair of lesions of the urinary bladder formed an additional impetus to the carrying out of this investigation.

METHODS

All experiments were performed on healthy adult cats of both sexes, a total of 24 animals being used. The animals were anæsthetized with intraperitoneal nembutal, and all operative procedures

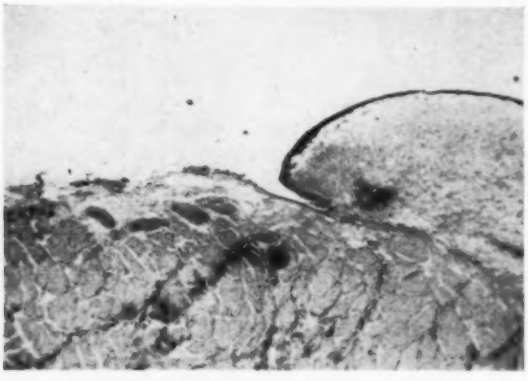

FIG. 130.—Section of ulcer margin at 1 day. Surrounding mucosa forms a rolled margin, and muscular tissue of the bladder wall forms the floor of the ulcer. H. and E. (× 28.)

were carried out under aseptic technique. The abdomen was opened through a midline incision, and the urinary bladder delivered through the wound. The contents of the bladder were evacuated through a small incision in the ventral wall; following this the incision was extended and the dorsal wall of the bladder was evaginated through the wound in the ventral wall by a finger of the assistant. An area of bladder mucosa approximately 1 sq. cm. in size was removed from the evaginated wall. The removal of the mucosa was facilitated by the plane of cleavage that exists between it and the muscular wall, and care was taken to avoid disturbing the mucosa surrounding the ureteral openings. Following this, the incision in the ventral wall was closed, using a continuous Connell suture and the abdominal wound was closed in layers.

The lesion created in the bladder is referred to throughout this paper as an ulcer.

The animals were killed at varying post-operative periods between the first and twenty-eighth days. The site of the bladder ulcer was then removed and fixed in ice-cold Carnoy's fluid. After embedding, serial sections 8μ thick were cut and every twentieth section mounted. These were stained with hæmatoxylin and eosin.

RESULTS

Gross Appearances.—The bladders of animals killed within three days of operation were always found to be in a contracted state, but at later periods their distension varied within normal limits. The urine was blood-stained for 24 hours after operation. The mucous membrane surrounding the ulcer frequently showed circumscribed areas of subepithelial hæmorrhage, but blood-clot in the floor of the ulcer was minimal. The ulcer in the early stages was easily defined; the epithelium at the margins had a raised and rolled appearance and the floor showed reddish granulation tissue. Later, with the increasing accumulation of granulation tissue, the rounded margin was no longer apparent. Still later, when complete epithelialization had occurred, the only evidence that an ulcer had

FIG. 131.—Ulcer margin at 1 day, showing cells spreading from the margin (right) over the ulcer floor. Note congested blood-vessels at the junction of normal and spreading epithelium. H. and E. (× 125.)

existed was the fact that the mucous membrane was thrown into a number of folds radiating from a small central depression.

Microscopical Appearances.—

Day 1.—At the end of 24 hours the ulcer bed consisted mainly of muscle-fibres with some overlying fibrin clot. The margin showed the rolled appearance that had been noted macroscopically (*Fig.* 130). From the epithelium of the margin a few cells had begun to spread over the periphery of the ulcer bed, sometimes in the form of a single layer, sometimes of a double layer (*Fig.* 131). Apart from the fact that these cells were occasionally flattened, they resembled those of the surrounding epithelium in that they were approximately the same size and gave the same staining reaction. No cells were seen in division either among those spreading over the ulcer bed or in the epithelium surrounding the ulcer. The subepithelial plexus of blood-vessels underlying the surrounding epithelium was distended with blood.

Day 2.—By the end of the second day the epithelium immediately surrounding the margin of the ulcer had become reduced in thickness to that of one or two cells (*Fig.* 132). This was a surprising finding in view of the fact that the bladders in the early post-operative days were always found to be in a contracted state, a state which is normally associated with epithelium many layers thick. Mitotic activity, which was entirely absent on the first day, had now become a striking feature. Cells in division were seen, firstly, in the normal epithelium some distance from the site of the ulcer (*Fig.* 133); secondly, in the thin epithelium immediately adjacent

to the margin of the ulcer (*Fig.* 132); and, thirdly, in the epithelium which had begun to spread over the floor of the ulcer (*Fig.* 134). This latter epithelium still consisted of one or two layers of cells which appeared to be loosely attached to the underlying tissue.

Days 3–4.—At this period there was evidence of the accumulation of granulation tissue in the ulcer bed in the form of polymorphonuclear leucocytic infiltration, young fibroblasts, and thin-walled blood-vessels (*Fig.* 135). The epithelium which had

FIG. 132.—Day 2. Thin epithelium immediately surrounding the margin of the ulcer. Note the presence of 2 mitotic figures. H. and E. (× 350.)

spread over the periphery of the ulcer had become stratified, now being three or four cells thick. This degree of stratification of the spreading epithelium persisted during all subsequent stages of healing. The advancing margin of the epithelium usually tended to be club-shaped, especially where it came into contact with organized granulation tissue (*Fig.* 135). Mitotic figures were still numerous.

Days 5–9.—Organization of the granulation tissue became evident. The leucocytic infiltration became less marked, and the fibroblasts underlying the epithelium were more tightly packed, and now tended to lie parallel to the surface (*Fig.* 136). At this stage the difference in appearance between the epithelium covering the floor of the ulcer and of the surrounding bladder was obvious (*Fig.* 137). The newly formed epithelium differed in that the cells were larger, the cytoplasm stained less densely, and the nuclei had a more vesicular appearance. Although mitotic counts have not been carried out in this work, there was an undoubted decrease in the frequency of mitosis in the regions where previously it had been most prolific.

Days 10–28.—The time taken for the epithelium to grow and spread over the floor of the ulcer depended on the size of the initial lesions. In the present experiments it was found that where the lesion had been approximately 1 sq. cm. in size, epithelialization was complete by the end of the second week. In the early stages following complete epithelialization, the site of the lesion could be recognized by cells whose appearances, as has been mentioned above, distinguished them from normal epithelium. In the later stages (28 days) the cells of the epithelium had an appearance similar to those of the rest of the bladder, and the level of mitotic activity seemed to be the same. It was also noted that a depression

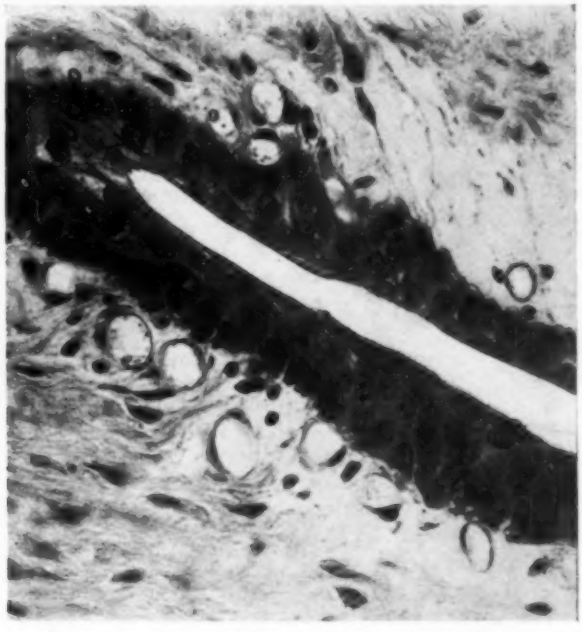

FIG. 133.—Day 2. Fold of epithelium some distance from ulcer site, showing normal stratification and three mitotic figures. H. and E. (× 350.)

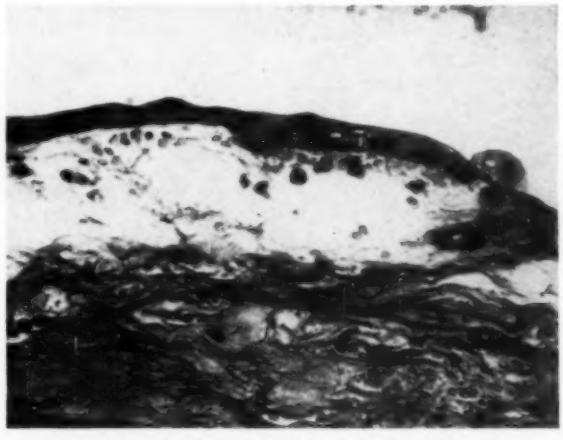

FIG. 134.—Day 2. A thin layer of epithelium spreading over the ulcer floor, showing a cell in the anaphase stage of mitosis. H. and E. (× 350.)

had formed and, in most of the specimens which were examined, it was found that the epithelium dipped down into the subjacent tissue in the form of downgrowths or crypts (*Fig.* 137). The persistence of the downgrowths during the period of observation and a slight increase in the vascularity of the subjacent tissues remained the only evidence of the lesion.

DISCUSSION

Although the urinary tract is frequently subject to inflammatory processes and traumatic injury due to calculi, ulcerative lesions are relatively rare, especially when compared with other hollow viscera

such as the intestine. Whilst this may be a true indication of the rarity of bladder ulceration, other factors may be involved. One significant factor may be the rapid rate of repair of transitional epithelium such as is demonstrated in the present studies.

It has been found that, in lesions involving only the mucosa, there is little or no macroscopical evidence of the lesion ten days after its production.

FIG. 135.—Day 4. Stratified epithelial cells advancing over organizing granulation tissue in the ulcer floor. H. and E. (× 80.)

FIG. 136.—Day 8. Section demonstrating the difference between newly formed epithelium (below) and normal epithelium (above) in the same bladder. Note also the difference in the subepithelial tissues. H. and E. (× 80.)

Microscopically, this rapid rate of repair has been found to be due to two processes which appear to supplement each other, and which consist of migration and increased mitotic activity. By the end of two days the surrounding epithelium has become thinned and epithelial cells have begun to spread over the periphery of the ulcer bed. This spreading continues and it is supplemented on the second day and during the subsequent four to five days by marked mitotic activity occurring both in the epithelium covering the ulcer floor and in that surrounding the ulcer. This pattern of growth of transitional epithelium in its normal site is similar to that which Johnson and McMinn (1955) found when bladder mucosa is transplanted to an abnormal site, such as the sheath of the rectus abdominis muscle. In that study the authors found that, on transplantation, transitional epithelium grows to form a completely epithelialized cyst. As in the case of the repair of the bladder ulcer, it was found that the growth of the transplanted epithelium consisted of two phases—migration and proliferation. Not only was the nature of the growth the same, but the time relationships were also similar, in that mitotic activity became apparent on the second day. In each case it has been found that the epithelial cells which were recently formed, either to repair the ulcer or to take part in the formation of a cyst, showed characteristics which distinguished the new epithelium from that of the parent epithelium, viz., the cells were larger, the cytoplasm stained less densely, and the nuclei had a vesicular appearance.

It is interesting to compare and contrast the reparative processes in transitional epithelium with those of other epithelia. A study of the literature indicates that, from the point of view of mitotic activity under normal conditions, epithelia can possibly be divided into two classes. One class comprises the epithelia of skin, cornea, and intestine, which display a high degree of proliferative activity, and the other includes tissues such as the epithelium

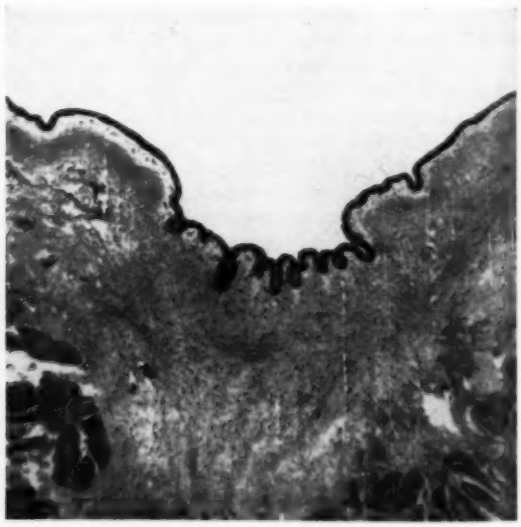

FIG. 137.—Day 28. Completely healed ulcer site, showing several epithelial downgrowths. H. and E. (× 30.)

of the ducts of exocrine glands and of the vascular tree and serous cavities, which show little activity. The response during the repair of these two classes of tissues also differs. In the epithelialization of skin wounds, migration of cells plays the primary role, without any significant increase in mitotic activity in the earlier stages (Arey, 1936). Friedenwald

(1950) points out that wounds of corneal epithelium heal by migration into the denuded area and that cellular multiplication plays only a later and secondary role. McMinn and Mitchell (1954) have shown that the healing of artificial ulcers in the small intestine is brought about by migration of the surrounding epithelium and not by any significant increase in mitosis. In contrast to these tissues, it is found that where mitosis is normally minimal, repair is characterized by proliferative activity at a relatively early stage, e.g., in the duct of the submaxillary salivary gland (Milstein, 1950). As far as transitional epithelium is concerned, it would appear from the present studies to fall into the latter category, since under normal conditions, cells in division are rarely seen and since healing of lesions is associated with marked cellular proliferation.

Although the reason for the different responses of epithelia to damage is not apparent, it might be speculated that where a tissue has a high resting activity, defects can be quickly repaired merely by lessening the loss of epithelial cells by surface shedding, whilst where the activity is low, rapid repair can be facilitated only by an increased rate of mitotic activity.

Not only does transitional epithelium differ from other stratified epithelia in its normal mitotic activity and in its activity during repair, but the early incidence of mitosis among its migrating cells would also appear to be a characteristic feature. Ivy, Grossman, and Bachrach (1952), in reviewing the process of epithelialization of skin wounds, point out that mitosis does not occur in the migrating cells until several days after they have become firmly fixed to the underlying tissue, i.e., at least four to five days after the production of the lesion. Corneal epithelium also differs from transitional epithelium, and behaves in a manner similar to that of skin, in that mitotic activity begins in the epithelium surrounding the lesion and does not in the early stages involve the spreading cells (Duke-Elder, 1954).

During the present work it has been noted that mitosis occurs in different layers of epithelial cells, a fact which supports the contention of Brauer (1926), who stated that mitosis is not confined to the basal layer.

The presence of epithelial downgrowths or crypts in the region of the healed ulcer confirms the findings of Giani (1907), who produced similar growths by curetting the urinary bladder. These downgrowths resemble the gland-like structures described by von Brunn (1893), Morse (1928), and others.

SUMMARY

1. Artificial ulcers of the urinary bladder have been produced in the cat by the removal of small areas of mucosa. The healing process has been studied histologically.

2. Epithelialization occurred by the initial migration of epithelial cells in a single or double layer from the ulcer margin, supplemented on the second and subsequent days by mitotic activity both in the migrating cells and in the cells of the surrounding epithelium.

3. Healing of an ulcer approximately 1 sq. cm. in size was usually complete by the end of the second week.

4. The early onset of mitosis in the migrating epithelial cells is contrasted with that which occurs in other stratified epithelia.

The authors wish to thank Professor Francis Davies for his helpful criticism and advice in the preparation of this paper. Thanks are also due to Messrs. J. H. Morrill and D. A. Allen for technical assistance and to Mr. J. H. Kugler for the preparation of photomicrographs.

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SHORT NOTES OF RARE OR OBSCURE CASES

SMALL-BOWEL OBSTRUCTION FOLLOWING PARTIAL GASTRECTOMY

By A. STANDEVEN, Hove

Attention has been drawn by Stammers (1954) to the occurrence of a form of small-bowel obstruction following gastrectomy. He collected 16 cases, in 15 of which the anastomosis was antecolic, where small intestine had passed through the gap between anastomosis and transverse mesocolon and had become obstructed. Five mechanisms were described with, in addition, one case of a similar nature in which the anastomosis was retrocolic, but the essential factor in all was the herniation of small-bowel behind the anastomosis either from right to left or from left to right. The difficulties of diagnosis were also discussed. It is probable that this condition is not so rare as the paucity of reported cases would suggest, and a more general awareness of its occurrence might lead to more frequent and earlier diagnosis. For this reason a further case, which illustrates how rapidly fatal it can be, is put on record.

CASE REPORT

A male patient, aged 46 years, was subjected to partial gastrectomy for chronic duodenal ulcer on May 21, 1954. The anastomosis was of Polya type, antecolic, afferent loop to lesser curve with formation of a valve, and the afferent loop was attached by two sutures to the base of the transverse mesocolon. The length of this loop was estimated at 9–12 in. There was some difficulty in controlling friable omental vessels at the lower pole of the spleen. The Ryle's tube was removed next day and his progress was normal until May 24, 1954, when at 10 a.m. he complained of sudden upper abdominal pain, radiating to the back, and was found to be perspiring freely with a rapid and weak pulse. There was no nausea or vomiting. A Ryle's tube was passed, 3 oz. of bile-stained fluid aspirated, and a blood transfusion commenced. Morphine ¼ gr. was administered.

At 12.30 p.m. he stated that he was feeling much better and had passed flatus. He was no longer sweating; the pulse was of normal pressure and volume, and the rate was 96 per min. All the abdominal signs were in the left upper quadrant and comprised tenderness, slight distension, and pain on movement, but no release pain or muscle guarding. Bowel sounds were reduced but of normal character. At noon 3 oz. of fresh blood had been aspirated from the stomach and a further 1 oz. was now produced.

It was clear that some intra-abdominal catastrophe had occurred. The possibility of retrograde intussusception was considered, but it was decided that the picture was most like an internal hæmorrhage, possibly from rupture of a subcapsular hæmatoma of the spleen produced in securing the troublesome bleeding points in this region. The bleeding into the stomach was unexplained by this diagnosis, but a further short period of observation was thought to be the wisest course.

At 2.0 p.m. there had been no further improvement despite continued transfusion, the pulse-rate was 100, and a further 3 oz. of blood had been aspirated. Laparotomy was decided upon, but whilst arrangements for this were being made the patient deteriorated rapidly with generalized abdominal pain and tenderness. Two pints of blood were rapidly transfused.

At Operation.—When the wound was re-opened under local anæsthesia much heavily blood-stained fluid escaped and a mass of distended and almost black bowel presented. This was delivered, and it was seen that with the exception of the last 2 or 3 ft. of ileum, all the small intestine had passed from left to right behind the anastomosis. When reduced there was some improvement in the colour of both bowel and mesentery, though it seemed likely that thrombosis had occurred in some, at least, of the mesenteric vessels. The extent was too great to permit of resection. The stomach was also very congested.

The patient vomited 14 oz. of blood in the theatre, but thereafter his condition improved. During the night, however, gradual deterioration occurred and he died at 6.0 a.m. Altogether 7 pints of blood were transfused.

Post-mortem examination was not performed, but it seems probable that the cause of death was mesenteric thrombosis.

COMMENT

Looking at this case in retrospect there are three features which should have led to the correct diagnosis. These are the sudden onset of the pain, the radiation to the back and the temporary shock indicating mesenteric involvement, and the aspiration of fresh blood from the stomach three days after operation in a patient whose convalescence was proceeding smoothly. The sequence of events was presumably strangulating obstruction at 10.0 a.m. and a fairly widespread mesenteric thrombosis causing the generalized abdominal pain and circulatory failure during the afternoon. It is possible that earlier re-opening of the abdomen might have saved the life of this patient.

The congestion of the stomach is interesting, for one must postulate that its venous drainage was in some way obstructed by the bulk of small bowel behind the anastomosis. Clearly this congestion was the source of the aspirated blood, the larger quantity of vomited blood coming from the upper jejunum when the obstruction was released. It is remarkable that blood is not more frequently found in the stomach in this group of cases where the afferent loop becomes highly congested, for one would expect it to leak back into the stomach. This occurred, however, in only one of Stammers' cases (personal communication).

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CHOLELITHIASIS SIMULATING PYLORIC NEOPLASM

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CASE REPORT

The patient, R. L., a man aged 72 years, was seen in February 1954, giving a history of having had discomfort in his epigastrium for four weeks. This came on as an acute attack of epigastric pain while he was at work. He was treated at home under his own doctor's care for three weeks and seemed to be improving. He then had a rigor and vomited and complained of further pain in his epigastrium.

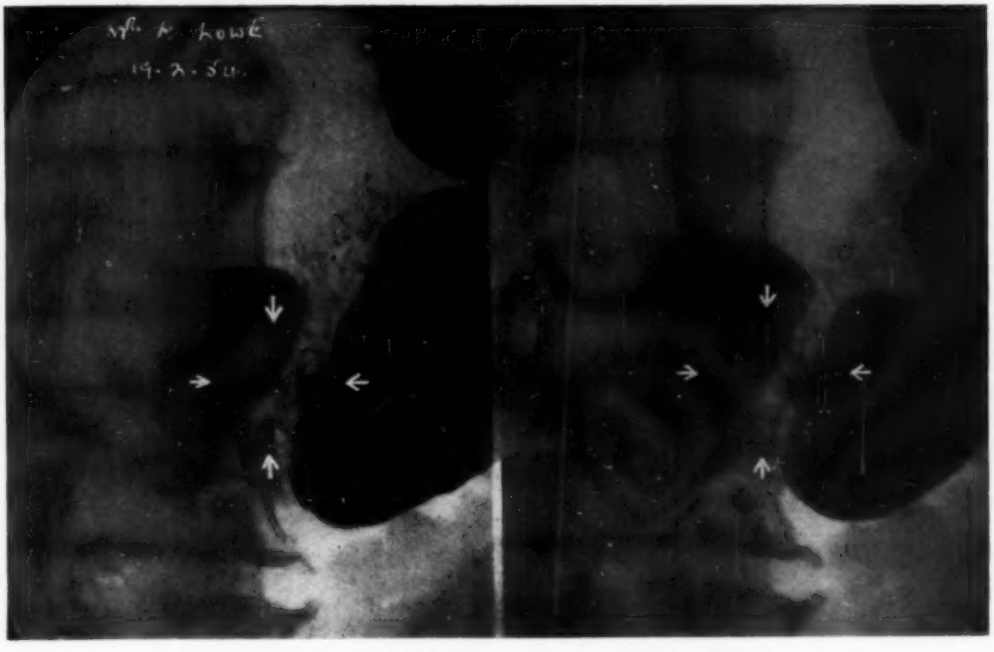

Fig. 138.—Radiograph showing constant filling defect at pylorus.

On Examination.—There was a smooth, large, non-tender mass on the right side of the epigastrium, which was suspected of being a carcinoma of the stomach or a large secondary in the liver.

A barium series was arranged and reported on as follows: "Screen examination of the chest revealed that the aorta was a little dilated. The lung fields were clear. Barium flowed normally down the œsophagus. No irregularity was demonstrated at the lower end of the œsophagus. The liver is enlarged. There is a persistent deformity at the pylorus; I found it extremely difficult to fill. There is a defect shown in all the films. This is not due to spasm and the appearance suggests that there is infiltration of the pyloric antrum, probably neoplastic." (*Fig.* 138.)

The patient's short history of epigastric pain and the marked loss of weight seemed to confirm the X-ray diagnosis. His general condition was poor, but it was thought that partial gastrectomy under local anæsthesia might be possible as a palliative measure.

At Operation.—On Feb. 26, under local anæsthesia, a midline incision disclosed a mass of adhesions under the liver around the gall-bladder and duodenum. Dissection revealed an inflammatory gall-bladder adherent to the anterior duodenal or pyloric wall, with penetration of the muscular wall but not of the mucous membrane (*Fig.* 139).

When the gall-bladder was separated from the anterior wall of the duodenum a fountain of small gall-stones sprayed up from the stomach opening. This phenomenon was explained by the fact that the mucous membrane had been separated from the wall for ¾ in. and this space had been packed with small faceted gall-stones.

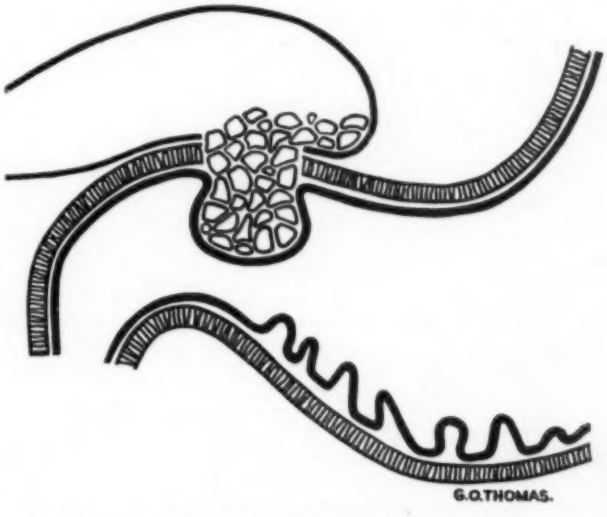

Fig. 139.—Diagram of condition found at operation.

Cholecystectomy was performed. The gap in the muscle wall at the pylorus was closed with interrupted catgut.

He made an uneventful recovery.

ADENOMA OF BRUNNER'S GLAND

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About a hundred years ago Cruveilhier first recorded a case of duodenal tumour. The diagnosis has been made with increasing frequency in the last twenty years because of better diagnostic facilities. Raiford reported the incidence of benign tumours of the intestine in 59,500 autopsies as 0·16 per cent. The majority were found in the duodenum and ileum. In 66 cases of benign duodenal tumour reviewed by Hoffman, 10·6 per cent arose in Brunner's glands.

Fig. 140.—The specimen. (× ⅔.)

In 1952, Hudson and Ingram found only 64 cases of adenoma of Brunner's gland recorded in the world literature. They noted that the incidence varied directly with the normal distribution of Brunner's glands, and that the tumours were usually sessile but could be pedunculated. The average size was reported as rarely exceeding 10 × 10 mm.

CASE REPORT

A 76-year-old female was admitted to hospital on Aug. 3, 1954. For six months she had complained of epigastric fullness and distress coincident with eating. Five days before admission she suddenly began to vomit coffee-ground material. She later fainted several times and had tarry stools. At no time did she complain of abdominal pain. There was no distension, tenderness, or masses, and her hæmoglobin was 59 per cent. She was transfused with 500 c.c. of blood but continued to have tarry stools. Four days later she had two bouts of coffee-ground emesis and became shocked. She received 1000 c.c. of blood in the next 24 hours.

On Aug. 10, 1954, she was admitted to the Toronto General Hospital. She was pale and obviously chronically ill. There was a mitral systolic murmur and a right reducible inguinal hernia. A cholecystectomy had been done eight years previously. There was a microcytic hypochromic anæmia with a hæmoglobin of 50 per cent and a normal N.P.N. The blood-pressure was 105/60.

Two upper gastro-intestinal series were done. The first demonstrated the presence of a small hiatus hernia, a duodenal ulcer, and a large duodenal bulb with an associated soft-tissue mass of an indefinite nature. On repeat examination the mass was interpreted as probably inflammatory in nature, and secondary to a duodenal ulcer.

She received further blood transfusions, but had no further evidence of bleeding. On Sept. 3, 1954, Dr. E. B. Tovee performed an exploratory laparotomy. Many adhesions were found in the right upper quadrant, presumably secondary to the previous cholecystectomy. A large mobile mass could be palpated in the second part of the duodenum, with its tip below the ampulla. A pyloric antrum incision was made and the tumour was delivered, removed, and the base oversewn. A routine

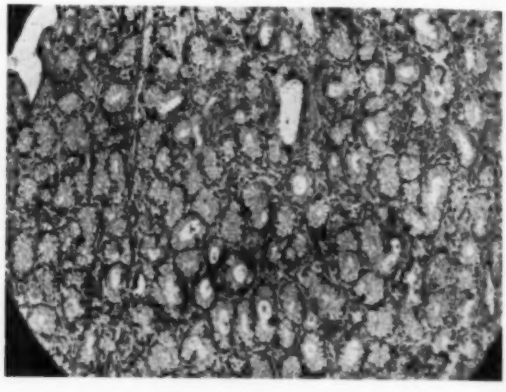

Fig. 141.—The uniform glandular pattern of the large adenoma of Brunner's gland.

closure was done. She made an uneventful recovery and was discharged ten days later.

Pathology.—

Gross: The mass measured 5·5 × 4·5 × 2 cm., and had a short pedicle and a nodular surface (*Fig.* 140). A large ulcer on the free surface measured 2 × 2·5 cm., and adjacent to this a small opening communicated with a narrow, smooth-walled central cavity, 2 cm. in length. A central greyish multi-lobulated area, measuring 4 × 2·5 cm., was present on cross-section. This contained several small mucinous cysts.

Microscopic: The central mass (*Fig.* 141) was formed by an orderly proliferation of Brunner's glands with a scanty supporting stroma, mild chronic inflammatory cell infiltration, and, occasionally, wisps of smooth muscle. The acini were lined by a single layer of columnar cells with flattened basal nuclei, pale granular eosinophilic cytoplasm, and a sharply demarcated basement membrane. The ducts were lined by cuboidal cells. Normal intestinal mucosa covered the mass and lined the cavity.

SUMMARY

This case is unusual because of the large size of the tumour and the absence of obstruction. Most of the recorded cases have had a vague history, a lack of definite findings, and have been discovered incidentally at autopsy. Nickolson, Henry, Singer, and Good (1952) reported a case in a 60-year-old man in which bleeding was the only symptom. The tumour measured 4·5 × 3·5 × 2·6 cm., and the pedicle 22 × 10 mm. While it is generally accepted that these tumours do not become malignant, Christie

(1953) reported a case of duodenal adenocarcinoma arising in Brunner's glands in an 80-year-old man.

The authors wish to acknowledge with thanks their indebtedness to Dr. Bruce Tovee for the clinical history and for permission to publish the case.

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REVIEWS AND NOTICES OF BOOKS

Transactions of the American College of Cardiology. Vol. III, 1953. 9¼ × 6¾ in. Pp. 259. Illustrated. 1954. New York: American College of Cardiology.

THIS volume, published in 1954, contains a series of papers delivered at a meeting in 1953, hence some of the material is not quite up to date. There is a useful series of papers on various aspects of congenital heart disease and a helpful one on the diagnosis of Bernheim's syndrome.

The Sherrington Lectures. III. The Invasive Adenomas of the Anterior Pituitary. By Sir GEOFFREY JEFFERSON, M.S. (Lond.), F.R.C.S., F.R.S., Emeritus Professor of Neurosurgery, University of Manchester. 8½ × 5½ in. Pp. 64, with 25 illustrations. 1955. Liverpool: University Press. 5s.

THE third Sherrington Lecture, recently delivered in the University of Liverpool, was the first since the death of Sir Charles Sherrington, whom the lecturer tells us died firm in religious beliefs that many lesser men abandoned. The lecture is now available in pamphlet form and is a masterly account of those tumours of the anterior lobe which invade the surroundings of the pituitary body and in this sense are malignant, though they do not metastasize outside the cerebrospinal axis and only very occasionally within it. Sir Geoffrey thinks that invasiveness probably occurs in about one-tenth of the pituitary adenomas. Ophthalmoplegia, trigeminal pain, or hypæsthesia, weakness of the masticatory muscles, and monocular blindness, signs of invasion of the cavernous sinus, are more commonly produced by aneurysms and nasopharyngeal tumours than by the pituitary adenomas, and while angiography may be helpful in distinguishing the aneurysms, he finds that good air encephalograms are better in recognizing the presence and limitations of pituitary tumours. This is a comprehensive and critical account, the result of direct observation by a distinguished master of his subject, and it adds an important page to our knowledge of the pituitary tumours.

Fractures and Joint Injuries. By Sir REGINALD WATSON-JONES, F.R.C.S., F.R.A.C.S. (Hon.), F.A.C.S. (Hon.), Extra-Orthopædic Surgeon to Her Majesty The Queen. Volume II, second edition. 9$\frac{5}{16}$ × 6½ in. Pp. 630 + x, with 904 illustrations, many in colour. 1955. London: E. & S. Livingstone Ltd. 120s. per set.

THE second volume of the fourth edition of this work appeared over three years after the first volume, but the delay is compensated by the masterly descriptions and excellent illustrations in this volume.

The average surgeon who deals with traumatic cases will find much to interest him in this second volume for it deals with injuries of the upper and lower limbs and the trunk. Most of the everyday traumatic cases come under this heading.

Watson-Jones has again given us a most useful book full of mature advice on a most important branch of surgery.

An Outline of the Treatment of Fractures. By the Committee on Trauma, the American College of Surgeons. 8¼ × 5¼ in. Pp. 98, with 45 illustrations. 1954. Chicago: The American College of Surgeons.

THIS small book gives an excellent account of current fracture treatment. There are points in the management of individual fractures which one might criticize, but this would be a matter of personal opinion. This is essentially an outline of treatment and as such is an extremely useful reference for the house surgeon and for others who have only occasional dealings with bone injuries. The illustrations of positioning of a patient for radiography of various bones are very well done and something of this type could be profitably included in a number of the larger text-books.

Early Care of Acute Soft Tissue Injuries. By the Committee on Trauma, the American College of Surgeons. 8¼ × 5¼ in. Pp. 194. Chicago: The American College of Surgeons.

THIS is an excellent concentrated account of the treatment of soft-tissue injury. It should prove of great value to the orthopædic surgeon who is faced on occasions with the treatment of certain injuries which do not usually fall within his field. There are few criticisms to make; one would have welcomed more operative detail in the management of vascular injury—particularly with regard to the use of arterial grafts; more stress might have been put on the value of secondary as opposed to primary suture in nerve injuries. On the whole a good practical handbook, and to be commended to all surgeons who have to deal with trauma.

Bone. By FRANKLIN C. MCLEAN, Ph.D., M.D., and MARSHALL R. URIST, M.D. 8½ × 5½ in. Pp. 182 + xii, with 25 illustrations. 1955. Chicago: The University Press. 45s.

THIS is a most useful and comprehensive monograph dealing with the histogenesis, structure, physiology, metabolism, and pathology of bone. There never has been a book in which all these subjects were considered together. The problems of intramembranous and intracartilaginous ossification of bone is set out in a very lucid way. The chemical composition of bone is considered and the crystal structure is discussed in detail.

To the surgeon there are many problems concerning bone such as resorption, the role of the osteoclast, and

phagocytosis. Then there is the growth hormone and dwarfism. All these problems are discussed in detail, as is the healing of fractures and what the authors term ' pathologic physiology of bone '.

A useful book for the clinician, surgeon, and research worker and an excellent reference volume.

The Principles and Practice of Surgical Nursing. By D. F. ELLISON NASH, F.R.C.S., Assistant Surgeon, St. Bartholomew's Hospital, London. 8½ × 5½ in. Pp. 1008 + viii, with 371 illustrations. 1955. London: Edward Arnold. 30s.

THIS is a new book on surgical nursing and it is written in a clear, refreshing style and is well illustrated with excellent photographs, charts, and radiographs.

The modern nurse if she reads this book will have little to fear at her State examination. All the various branches of surgery are dealt with in an interesting manner and the fundamental principles of surgery are clearly set out and carefully explained.

This is a book which should prove a boon to Sister Tutors for it contains all that a nurse should know.

The clinical photographs have been well chosen with the exception of Fig. 9, which depicts a rodent ulcer of the anus—surely a most uncommon site for this neoplasm.

This book we are sure will prove to be most popular with the nursing profession.

Fluid and Electrolytes in Practice. By HARRY STATLAND, M.D., Associate in Medicine, University of Kansas School of Medicine; etc. 9 × 6 in. Pp. 206 + xiv, with 30 illustrations. 1955. London: Pitman Medical Publishing Co. Ltd. 35s.

MODERN surgery demands a thorough knowledge of fluid balance in the body if adequate post-operative care is to be given to the patient. The management of fluid balance is essential to the quick recovery and the contentment of the surgical case.

This monograph provides a thorough coverage of the present-day knowledge of this vital aspect of medical and surgical treatment.

Many operations which are performed to-day on the alimentary tract are not only severe but are very intricate and demand a considerable amount of time. Blood transfusion and replacement of electrolytes are frequently required. It is essential that any abnormality in the volume concentration and acid-base balance of the patient should be corrected as soon as possible.

This book, written in a lucid yet very practical style, gives all the answers and should prove invaluable to house surgeons, registrars, and also to surgeons.

Hernia. The Pathologic Anatomy of the More Common Hernias and Their Anatomic Repair. By CHESTER B. MCVAY, M.D., Ph.D., Clinical Professor of Surgery and Associate Professor of Anatomy, The University of South Dakota School of Medical Sciences. 11 × 8⅜ in. Pp. 40 + xvi, with 19 illustrations. 1954. Springfield, Ill.: Charles C. Thomas. (Oxford: Blackwell Scientific Publications.) 34s.

THIS is in reality an atlas presenting a series of drawings illustrating the various stages in operative techniques in the treatment of the common herniæ. Of necessity, the description of the anatomy and the operative procedures are detailed, and give the reader a very good picture of what is required in the repair of herniæ.

The atlas fulfils its purpose—namely, to present concisely the present methods of repairing the more common herniæ, with the constant underlying principle of restoring abnormal to normal anatomical architecture.

Segmental Anatomy of the Lungs. A Study of the Patterns of the Segmental Bronchi and Related Pulmonary Vessels. By EDWARD A. BOYDEN, Ph.D., Professor Emeritus of Anatomy, the Medical School, University of Minnesota. 10⅜ × 6¾ in. Pp. 276 + xx, with 125 illustrations and 12 plates. 1955. New York and London: McGraw-Hill Book Co. Inc. 112s. 6d.

ALTHOUGH Brock and others have written extensively concerning the anatomy of the bronchial tree, yet this large monograph by Boyden is the first comprehensive work to show the relation of arteries and veins to segmental and subsegmental bronchi and to employ a uniform system of naming and numbering related bronchi, arteries, and veins. It is the first work to extend the analysis of bronchial and vascular structures to subsegmental levels.

Professor Evarts Graham, who writes a foreword to this book, says, " Every chest surgeon will welcome this book and everybody having any interest in the lungs will welcome it". We quite agree with Dr. Graham, for the author has written a book in which the anatomist, the bronchoscopist, the radiologist, and the pathologist will find much to interest them.

During the last decade advances in thoracic surgery and the developments of the techniques of pulmonary resection have brought an urgent demand for greater knowledge of lung structure and accurate information on the boundaries of the segments and the distribution of the branches of the bronchi and blood-vessels. All this information is to be found in this book.

The illustrations are quite a feature of this work and are beautifully produced.

As a reference volume on the anatomy of the lung the book has no equal.

Pain. Its Mechanisms and Neurosurgical Control. By JAMES C. WHITE, M.D., F.A.C.S., and WILLIAM H. SWEET, M.D., F.A.C.S., Massachusetts General Hospital and Harvard Medical School. With assistance in the Psychiatric Sections from STANLEY COBB, M.D., and FRANCES J. BONNER, M.D. 10 × 7 in. Pp. 736 + xxiv, with 134 illustrations. 1955. Springfield, Ill.: Charles C. Thomas. (Oxford: Blackwell Scientific Publications.) 126s.

THIS large monograph is dedicated to Sir Geoffrey Jefferson and Wilder Penfield, two neurosurgeons from whom the authors have learned so much that they hold of value in the science and art of neurosurgery. Such a dedication at once whets the appetite of the reader, and he is not disappointed, for within the covers of this book a very comprehensive clinical survey of the whole field of painful conditions is undertaken.

The book is the first monograph dealing with all phases of pain transmission and its surgical interruption since Foerster's classical treatise written a generation ago.

The book is divided into three main parts; the first dealing with the fundamental aspects of pain; the second with surgical technique in the treatment of pain; while the third is devoted to the treatment of specific painful conditions such as the neuralgias.

An important chapter on the psychological aspects of organic pain is written by Dr. Stanley Cobb, former Chief of the Psychiatric Service, Massachusetts General Hospital; he is assisted in this by his associate, Dr. Frances Bonner.

The whole volume is full of clinical cases which, in themselves, demonstrate the value of various forms of surgical treatment.

The illustrations throughout the book are excellent and help to enhance the value of this important work.

A pre-eminent and admirable monograph which will take its place as one of the really useful books in surgical literature.

Babcock's Principles and Practice of Surgery. Edited by KARL C. JONAS, B.S., M.D., M.S. (Surg.), F.A.C.S., F.I.C.S., Department of Surgery, Temple University School of Medicine and Hospital, Philadelphia, Pa. 10 × 7 in. Pp. 1543, with 1006 illustrations. 1954. London: Henry Kimpton. 135s.

DR. JONAS has a very formidable list of contributors who have assisted him in revising Babcock's well-known book on surgery. All the many contributors are well-known teachers in surgery or special branches of surgery, therefore it contains the hall-mark of American Surgery.

An excellent section is devoted to military surgery, which contains all the latest techniques and operations which come under the heading of plastic and reconstructive surgery. This section is of real importance to-day for in this mechanical age many accidents, often severe ones, occur every day both in America and England.

General surgery is covered in a very practical manner, while the special branches of cardiac and orthopædic surgery and neurosurgery are almost rewritten.

This large volume will continue to be the reference book of the senior registrars and surgeons, but we hope the editor will insist on two volumes next time, for the present one-volume book is very heavy and cannot be read comfortably in a chair.

Bickham-Callender's Surgery of the Alimentary Tract. By RICHARD T. SHACKELFORD, M.D., Assistant Professor of Surgery, Johns Hopkins University School of Medicine; assisted by HAMMOND J. DUGAN, M.D. In three volumes, 10 × 7 in. Pp. 2575 + 89-pp. Index, repeated in each vol. With 1705 illustrations. 1955. Philadelphia and London: W. B. Saunders Co. Ltd. £21.

SOME of the more senior British surgeons will remember the monumental work of Dr. Warren Stone Bickham, of New York, which appeared in 1924. It was encyclopædic and covered the operative surgery of the whole body at that time. Dr. Latimer Callender undertook a second edition and worked with this end in view from 1938 until his death in 1947. In 1949 Dr. Shackelford took over the reins and worked at a complete revision, and the present three volumes are the result of his labours.

The complete work is very comprehensive and covers the whole field of the surgery of the alimentary tract. During the last decade vast strides have been made in the surgery of the intestinal canal. The surgery of the œsophagus has come into its own and partial or complete excision of this part of the gut is now commonplace. The surgery of the stomach and the colon has been extended and far more radical procedures are now undertaken than ever before. Tumours of the liver and pancreas are now excised with a low mortality.

Dr. Shackelford has covered this extensive surgical field in an admirable manner and has given his assessment of the various operative procedures which is most valuable. The illustrations throughout the three volumes are consistently good and are a real help to the reader, and many of them are new and original. There is too great a tendency to-day to modify drawings from other books or papers, which is a mistake.

We have few criticisms to make, but we think in England few surgeons would use a knee pillow to maintain a patient in the Fowler's position because of the possibility of venous thrombosis and embolism.

New words are still creeping into surgical literature, some are good and some are bad; the words fistulotomy, and fistulectomy, have little to recommend their use, but this denotes a modern tendency which should be curbed.

This work will appeal to the abdominal surgeon and it will be his source of reference for a long time.

The Year Book of Neurology, Psychiatry, and Neurosurgery. Edited by ROLAND P. MACKAY, M.D. (Neurology); S. BERNARD WORTIS, M.D. (Psychiatry); PERCIVAL BAILEY, M.D., and OSCAR SUGAR, M.D. (Neurosurgery). 7⅝ × 5⅛ in. Pp. 619, with 97 illustrations. 1955. Chicago: Year Book Publishers Inc. (London: Interscience Publishers Ltd.) 53s.

THE year's contributions to these branches of study of the nervous system are considered with appropriate comments by the editors. Some of their remarks are rather pithy, as for instance that it was a "naughty test", instructive but scarcely surprising, which revealed that there were differences in the interpretation of electroencephalograms by experts shown the same tracings. Some readers may be a little disturbed by the statement that psychiatry is turning from preoccupation with the needs of the individual patient to the combined needs of the family and the community! It is of interest to note that prefrontal leucotomy in neuropsychiatric cases has been prohibited by the Minister of Public Health for the U.S.S.R. on the ground that "it contradicts the basic principles of the physiological teachings of I. P. Pavlov".

The non-chromaffin paraganglioma of the petrous bone, which has been given a variety of names but which we usually call the jugular body tumour, is here referred to as Otani's tumour.

Perhaps the most recent developments to interest those who operate on the nervous system are induced hypotension and hypothermia, the indications for and contra-indications to which are still being considered. The present position is discussed in this book.

In common with its fellow year books, this is a valuable publication from which the progressive practitioner as well as the student of the various aspects of neurology will derive much useful information.

Professional Negligence. By J. P. EDDY, Q.C. With a Foreword by the Right Honourable Sir ALFRED DENNING. 8 × 4⅞ in. Pp. 146 + xii. 1955. London: Stevens & Sons Ltd. 13s. 6d.

THIS book appears at an opportune moment when medical men in this country are worried about the great increase in litigation since the National Health Service has come into being.

It should be remembered that payments made by hospital authorities in compensation of all kinds were £7,500 in 1948 and £153,000 in 1953. These figures speak for themselves.

Mr. Eddy in this little monograph sets out in a lucid way the liability of professional men for negligence, and cites over 100 cases.

The book itself is based on the Travers Memorial Lectures delivered this year at the City of London College.

An Atlas of Musculoskeletal Exposures. By H. F. MOSELEY, M.A., D.M., M.C.S. (Oxon.), F.R.C.S., F.A.C.S., Hunterian Professor, Royal College of Surgeons of England; Assistant Professor of Surgery, McGill University. 11 × 8¼ in. Pp. 235, with 376 illustrations in colour and 63 figures in black and white. Illustrated by HELEN T. MACARTHUR, B.A. 1955. London: Pitman Medical Publishing Co. £9.

THIS is an atlas showing the various incisions, exposures, and techniques of various orthopædic operations.

Anatomical structures are built up pictorially and descriptively layer by layer from the framework of the skeleton outwards to the skin surface.

The use of colour in the illustrations adds to the value of the book.

The book includes consideration of skin preparation and illustrates various aspects of the posturing and

draping of the patient for the operative exposures in question.

The whole book shows a very practical outlook on the part of the author, who has spent many years in the study of shoulder lesions and has now incorporated his experience with other joints of the body.

The Abnormal Pneumoencephalogram. By LEO M. DAVIDOFF, M.D., Professor and Chairman, Department of Surgery of the Albert Einstein College of Medicine, and Director of Surgery, Bronx Municipal Hospital Center; Chief of Neurosurgery, Mount Sinai Hospital, New York, N.Y.; and BERNARD S. EPSTEIN, M.D., Chief, Department of Radiology, The Long Island Jewish Hospital, New York, N.Y. Second edition. 10 × 7 in. Pp. 518, with 291 illustrations. 1955. London: Henry Kimpton. 110s.

THE second edition of this work has been very thoroughly revised and considerable new material has been added and many new illustrations incorporated in the text. Although angiography and the use of radio-isotope localization have to some measure taken the place of encephalography, yet it still remains a very helpful procedure. Neurologists and neurosurgeons will still rely on encephalography in different cases. With better X-ray pictures the present-day neuroradiologist can be very helpful in making the localization of a cerebral tumour more certain.

This book will prove a useful reference volume where quick decision is necessary in any particular case. The book also demonstrates in no uncertain way the real value of encephalography.

Fractures in Children. By WALTER PUTNAM BLOUNT, A.B., M.D., F.A.C.S., Chairman of the Orthopedic Section, Milwaukee Children's Hospital. 10 × 6¾ in. Pp. 279 + x, with 311 illustrations. 1955. Baltimore: Williams & Wilkins Co. (London: Baillière, Tindall & Cox.) 72s. 6d.

THIS monograph devoted to the treatment of fractures in children describes in detail the author's various methods of reduction, splintage, and plaster technique. With twenty years of experience as his background one would expect Dr. Blount to produce a good book, and one is not disappointed, for this monograph is written in a lucid style with plenty of good illustrations to supplement the text. The numerous radiographs are excellent and are beautifully reproduced.

Surgeons and practitioners alike will find this book of real value to them.

Mysterious Waters to Guard. Essays and Addresses on Anæsthesia. By WESLEY BOURNE, M.D., C.M., M.Sc., F.R.C.P.(C.), F.I.C.A., D.A. (B.C.P. & S. Eng.), F.A.C.A., F.F.A.R.C.S., Emeritus Professor of Anæsthesia, McGill University. 9¼ × 6⅛ in. Pp. 398 + xvi. Illustrated. 1955. Oxford: Blackwell Scientific Publications. 42s.

THIS large collection of lectures given by Dr. Wesley Bourne make fascinating reading for the author covers such a vast field not only in physiology but also in pharmacology in their relation to anæsthesia.

Doctor Bourne has spent a lifetime devoted to anæsthesia and has seen his speciality go from strength to strength until to-day it is one of the important branches of modern medicine. The advances of surgery would be greatly limited if it were not for the great help given by the anæsthetist.

The title of this book is sound for, as the author explains, the anæsthetist must have a knowledge of pharmacology and biochemistry if he is to be able to guard his patient through the difficulties and even dangers of modern anæsthesia.

All through the lectures contained in this volume runs the theme of alleviating suffering, and the author's reflections on anæsthesia as both an art and a science will be of interest not only to his own profession but also to a wide circle of thinking men.

An excellent volume of essays and addresses on anæsthesia.

The Genesis and Prevention of Cancer. By W. SAMPSON HANDLEY, M.S., F.R.C.S., Senior Consulting Surgeon to the Middlesex Hospital; etc. Second edition. 8½ × 5⅜ in. Pp. 320 + xx, with 114 illustrations. 1955. London: John Murray. 21s.

THE new and revised edition of this book sets out in great detail the author's well-known views on the genesis of cancer. Taking as a hypothesis that malignant growth stems from obstruction to lymphatics, the processes involved in such a transition are described step by step. Firstly there is a very full account of the lymphatic anatomy of the skin, with a number of illustrations of the histology. There follows an account of lymphangitis and the effect which this has upon the tissues which the lymphatics drain. Various examples of papilloma formation following lymph stasis are cited, and the theory is exemplified by reference to skin papillomata, papillomata of the larynx, and polypi of the stomach, all allegedly precancerous conditions, and all, according to the author, stimulated by lymphatic obstruction. A large number of pathological instances are quoted to illustrate this link, including adenomata of the thyroid with papilliferous changes, papillomata in fibro-adenosis of the breast, and papillomata elsewhere in the body. There is a pertinent discussion on the pathology of lupus and the transition of this disease to malignancy. Having established the relation between lymph stasis and papilloma, the second stage, namely that between papilloma and carcinoma in many sites throughout the body, is convincingly demonstrated.

The work illustrates the very considerable thought which the author has devoted to the subject of carcinogenesis throughout a long and distinguished life.

Essentials of Orthopædics. By PHILIP WILES, M.D., F.R.C.S., F.A.C.S., Senior Orthopædic Surgeon, The Middlesex Hospital, London; etc. Second edition. 9⅝ × 6¼ in. Pp. 538 + xvi, with 393 illustrations. 1955. London: J. & A. Churchill. 65s.

DURING the last six years Mr. Wiles' text-book has probably become the leading standard work on orthopædics in Great Britain and the appearance of a second edition is, therefore, important. There has been some mild inflation though no more than is occurring with such depressing regularity in so many other fields. There are 75 more pages and about 30 more figures; the price has increased from 42s. to 55s. There is no great harm in this, but it is vital that at some point an author should set his face against further expansion of a successful book. As new material is always coming forward this can be done only by re-arrangement and pruning. A few features have been omitted such as the discredited osteotomy of the base of the first metatarsal for hallux valgus in young people. This is good, but there might have been more such omissions. In twenty-five years' experience of orthopædics we have never seen a case of weaver's bottom or a genuine example of intermittent hydrarthrosis. Even if these conditions have come within Mr. Wiles' experience he could well omit them. The rather unusual arrangement of the work is unchanged. The first nine chapters of the book deal with orthopædic disorders regionally, the other six are based on pathology.

At first sight there appear to have been very few changes, but close examination of the two editions shows that the editing has been carried out with quite exceptional care. There are many small deletions; there are even more welcome additions such as the references to vertebral instability, to Ponseti and Friedman's and to James' work on scoliosis, and to osteoid osteoma. Some of the illustrations are better, too, though a few that should have been changed remain, for example, those of the most harmful banjo type of splint for Volkmann's ischæmia and the obsolete plaster fixation for a patient with poliomyelitis. The standard of production is as good as ever and we have no hesitation in again recommending this text-book to the medical student and the general practitioner.

Surgery of the Small and Large Intestine. By CHARLES W. MAYO, M.D., Mayo Clinic, Rochester, Minn. 8¼ × 5⅝ in. Pp. 340, with 94 plates in the text. 1955. Chicago: The Year Book Publishers. (London: Interscience Publishers Ltd.) 68s.

THIS is one of the really useful books for surgeons for it is written by a surgeon who has a great clinical background and has used his experience to the great advantage of the reader. There are some 94 plates each of which contains up to six operation sketches showing the various stages of different operations.

The various operative procedures which are carried out on the small and large intestine are described in a concise way, and there is no sign of repetition throughout the book. The first chapter is devoted to the diet of the patient who is to undergo surgical intervention for different conditions. The pre-operative diet is discussed in detail and specimen menus are given, together with the weight and approximate measure of the food. The post-operative diet with its minimum residue and low-residue types are given in full. This is a most useful section and is full of valuable information to the surgeon and should prove useful in those institutions which have not the services of a trained dietician.

Most of the illustrations in this book are quite original and they demonstrate the value of the appointment of a whole-time artist in any hospital, for he is available at a moment's notice to make a sketch of any abnormality or pathological condition found at operation.

A most useful book.

Advanced Surgery of Cataract. By DANIEL KIRBY, M.D., F.A.C.S., Professor Emeritus of Ophthalmology, New York University College of Medicine. 10 × 6¾ in. Pp. 271 + xiv, with 138 text illustrations and 22 coloured plates. 1955. Philadelphia: J. B. Lippincott Co. (London: Pitman Medical Publishing Co.) £11.

THIS *de luxe* monograph is in reality a companion work to Dr. Kirby's well-known book on Surgery of Cataract, which enjoys an international circulation.

The present volume is profusely illustrated with 138 figures in black and white and 96 beautiful colour drawings.

Dr. Kirby's clinical and operative experience is great, for he has devoted his professional life to this subject and, therefore, he speaks with that mature knowledge which is seen in the pages of this book. The everyday problems which beset the ophthalmic surgeon who deals with cataract cases are excellently portrayed. The advanced use of curare and local anæsthesia in this branch of surgery is discussed in detail, while palpebral and retrobulbar injections for anæsthesia and akinesia are advocated in certain cases.

The minute operation details and techniques are well described and illustrated and anyone who wishes to perform operations for cataract should certainly read this book, which is beautifully produced.

Surgery of the Sympathetic. By ALEXANDER LEE MCGREGOR, F.R.C.S., Consulting Surgeon, Johannesburg General Hospital. Pp. 192 + v. 1955. Bristol: John Wright & Sons. 30s.

ALTHOUGH much has been written about the surgery of the sympathetic system in the last thirty years, yet there is a place for an up-to-date and concise book on the subject.

Lee McGregor has written extensively on the sympathetic system and has travelled abroad to see other surgeons who have made the surgery of the sympathetic their particular field of surgical research.

After the first world war operations on the sympathetic system were many and varied; to-day, after trial and error and extensive research, our ideas have crystallized as to the real place of surgery in sympathetic derangements.

This monograph sets out in a lucid way the indications for operations on the sympathetic system, and they are found to be few. These operations are described in detail and there can be little doubt that this book will prove of value to the student and surgeon alike.

Neuro-vascular Hila of Limb Muscles. By JAMES COUPER BRASH, M.C., M.A., M.D., D.Sc., LL.D., F.R.C.S.Ed., F.R.S.E., Professor Emeritus of Anatomy, University of Edinburgh. 9¾ × 7½ in. Pp. 100 + xvi with 30 coloured illustrations. 1955. Edinburgh: E. & S. Livingstone Ltd. 30s.

THIS is an important work and is in reality an atlas with thirty coloured plates all of which depict the mode of entry of the principal arteries of supply to the limb muscles. Quite commonly the principal blood-supply of the muscles is associated with the nerves commonly known as the 'neurovascular hilum'.

Although several workers in the past have written on this subject yet there was a necessity to investigate this subject once again so that the modern surgeon should have an up-to-date and an accurate atlas for ready reference. This is important in this mechanical age when traumatic surgery is so often required.

This atlas will be found of real use to all those interested in exact data on the mode of the blood-supply and nerve-supply of the limb muscles.

A very useful book.

The Lung. Clinical Physiology and Pulmonary Function Tests. By JULIUS H. COMROE, jun., M.D., ROBERT E. FORSTER, II, M.D., ARTHUR B. DUBOIS, M.D., WILLIAM A. BRISCOE, M.D., and ELIZABETH CARLSEN, A.B., Graduate School of Medicine, University of Pennsylvania. 9 × 6 in. Pp. 219 + viii, with 56 illustrations. 1955. Chicago: Year Book Publishers. (London: Interscience Publishers Ltd.) 40s.

THIS book, published by a group of workers of the Graduate School of Medicine of the University of Pennsylvania, is a useful contribution to pulmonary physiology and is especially written for clinicians. It is divided into three parts. The first is devoted to experimental work on Lung Volumes, Pulmonary Ventilation, Pulmonary Circulation, Diffusion, Arterial Content of Oxygen and Carbon Dioxide, and the mechanics of breathing.

The second part deals with the clinical application of these functional tests, and the third part—an appendix—supplies useful data, equations, and calculations.

These tests are now becoming a *sine qua non* to those engaged on this subject, and although they do not supplant the old-established diagnostic procedures, give an important indication of the effects on function from disease, and of responses to therapy. Many of them can be done in the consulting room as a means of evaluating

the mechanical factors in breathing, and are a useful help to diagnosis. The text, if in places somewhat technical, is illustrated by simple schematic illustrations.

The tests give positive evidence in such conditions as hypoventilation caused by lesions of the medullary centres, in asthma, emphysema, silicosis, tumours causing displacement, respiratory acidosis during anæsthesia. Although no definite criteria have been developed for pre-operative lobectomy, evidence is available where surgery is contra-indicated in extensive bilateral disease.

Physiological jargon is avoided, and the book commends itself to all those interested in diseases of the chest and anæsthesia.

Surgical Forum. Clinical Congress of the American College of Surgeons 1954. By various contributors. Vol. V. 9⅝ × 6¼ in. Pp. 851 + xl. Illustrated. 1955. Philadelphia and London: W. B. Saunders Co. Ltd. 70s.

THIS large volume contains the various papers that were read at the fortieth clinical congress of the American College of Surgeons at Atlantic City in November, 1954. The various papers cover the extensive field of modern surgery and surgical research.

It would be impossible to review the many papers in this volume, but the outstanding feature is the extensive animal research at the present time. Pualwan and others have studied the effects of ligation of the inferior vena cava with absorbable gut in some 45 dogs and have found that 85 per cent of operative survivors have shown deligation and reconstruction of the lumen by X-ray examination and autopsy. Thrombosis was frequently noted distal to the ligation. It was found that ligation of the inferior vena cava caudal to all the lumbar veins resulted in an appreciable immediate mortality while ligation cephalad to lumbar veins did not.

There are many papers on vascular grafts and vascular research; and on nutrition, body fluids, and metabolism.

The problem of steroids and cancer is fully discussed in various papers, while the role of epinephrine in hyperkalæmia of acute experimental burns makes interesting reading.

There is no lack of experimental surgical research in the American College of Surgeons, and this large volume should stimulate surgeons of other lands to further their interests in this work.

Pathology for the Surgeon. By WILLIAM BOYD, M.D., LL.D., M.R.C.P., F.R.C.P., F.R.C.S., Lecturer on the Humanities in Medicine, University of Toronto; Visiting Professor of Pathology, University of Alabama. Seventh Edition. 10 × 7 in. Pp. 737 + vi, with 547 illustrations including 10 in colour. 1955. Philadelphia and London: W. B. Saunders Co. Ltd. 87s. 6d.

IT is some thirty years ago that William Boyd's *Surgical Pathology* saw the light of day and was hailed by surgeons both at home and abroad as one of the essential books for every surgeon. Since that date six new editions with numerous reprints have appeared, and now the seventh edition, with a slight change of title.

Osler wrote years ago, "as is our pathology so is our practice"; this holds good to-day, for surgical practice depends on our knowledge of pathology.

This new edition is really a new book with new format and a new title.

It will still take an honoured place as a reference volume in the library of surgeons, for it still has much knowledge in its pages.

BOOK NOTICES

[*The Editorial Committee acknowledge with thanks the receipt of the following volumes. A selection will be made from these for review, precedence being given to new books and to those having the greatest interest to our readers.*]

The Year Book of Urology, 1954–1955. Edited by WILLIAM WALLACE SCOTT, M.D., Ph.D., The Johns Hopkins Hospital. 7½ × 5 in. Pp. 372, with 83 illustrations. 1955. Chicago: The Year Book Publishers. (London: Interscience Publishers Ltd.) 45s.

Cardiac Anomalies. A Clinicopathologic Correlation. By VINCENT MORAGNES, M.D., Associate Professor of Pathology, Creighton University School of Medicine, Omaha, Nebr.; and CHESTER P. LYNXWILER, M.D., Assistant Professor of Pediatrics, St. Louis University School of Medicine, St. Louis. 11 × 8½ in. Pp. 92 + x, with 157 illustrations. 1954. Baltimore: Williams & Wilkins Co. (London: Baillière, Tindall & Cox.) $6.50.

Erlebtes aus der Thoraxchirurgie. By Prof. Dr. RUDOLF NISSEN, Director of University Surgical Clinik, Basel. 10½ × 7¼ in. Pp. 64, with 99 illustrations. 1955. Stuttgart: Georg Thieme. DM. 14.40.

Clinical Neurosurgery. Proceedings of the Congress of Neurological Surgeons, New Orleans, La. 9 × 6 in. Pp. 201 + viii, with 89 illustrations. 1955. London: Baillière, Tindall & Cox. 61s. 6d.

Atlas de Chirurgie Thyroïdienne. By JACQUES FRANCILLON and CLAUDE GABRIELLE, Lyons. With a Foreword by LÉON BÉRARD. 10⅝ × 7½ in. Pp. 182 + vi, with illustrations by Dr. C. MILLET. 1955. Paris: Expansion Scientifique Française.